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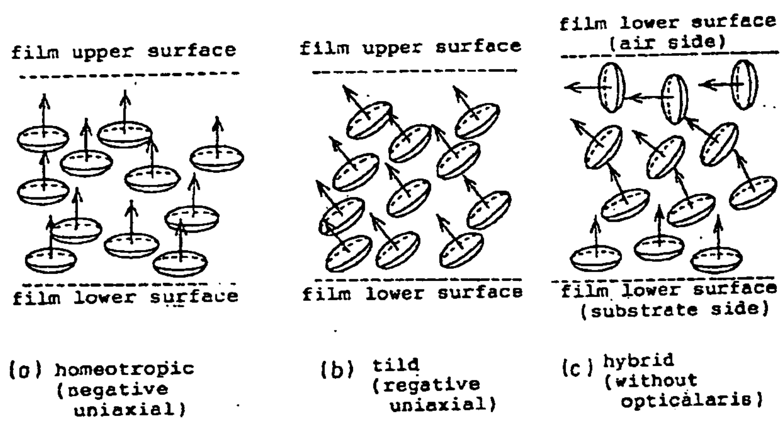
(54) LIQUID-CRYSTALLINE OPTICAL FILM AND ITS UTILIZATION

(57) A new liquid crystalline optical film obtained hybrid-orienting and solidifying discotic liquid crystal uniformly over an large area is provided.

The liquid crystalline optical film is formed by a single-layered film made of a discotic liquid crystalline material in which an orientation form of the discotic liquid crystal is solidified, and the orientation form is a hybrid orientation form such that the angle between discotic liquid crystal directors near the upper interface of the film and the film plane is different from the angle between discotic liquid crystal directors near the lower interface of the film and the film plane. Therefore, the liquid crystalline optical film exhibits an excellent effect as a compensating plate especially for a liquid crystal display.

Fig. 2



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a novel liquid crystalline optical film and its utilization, and more specifically, a liquid crystalline optical film in which an orientation form of discotic liquid crystal is stabilized, its utilization as a compensating film for liquid crystal display element and a liquid crystal display incorporating the liquid crystal optical film.

Description of the Prior Art

A liquid crystalline optical film in which an orientation form of liquid crystal is stabilized shows a peculiar optical feature coming from a liquid crystal structure, and it is an unique material presenting excellent endurance against environment. The liquid crystal generally has strong birefringence, and its orientation form is diversified. Thus, the liquid crystal can display optical ability which cannot be obtained by a birefringent stretched film, etc.

In these years, in order to utilize the feature of the liquid crystal, in particular, the peculiar optical feature accompanied by the orientation form, various reports have been made on the stabilization of the orientation.

Since nematic liquid crystal, smectic liquid crystal and cholesteric liquid crystal which have been examined are such that rod-like liquid crystal molecules are oriented, variety of obtained orientation forms is limited, and thus the application of the liquid crystal to new optical fields and coping with required physical properties have reached the limit.

Therefore, the discotic liquid crystal whose molecular shape is entirely different from that of the above liquid crystal has attracted attention, and thus the discotic liquid crystal is tried to be utilized in the optical fields, etc. similarly to the above liquid crystal.

The discotic liquid crystal is generally such that the molecules have disc-like shape and when the liquid crystal is oriented on a substrate, a homeotropic orientation, in which the molecular plane is parallel with a surface of the substrate, or a tilt orientation, in which the molecules are tiled at a constant angle, are obtained. A refractive index structure which is shown by the above orientations is a negative uniaxial structure.

The utilization of the discotic liquid crystal in the optical field is disclosed in, for instance, Japanese Patent Application Laid-Open No. 6-214116/1994. This publication discloses an optical element producing method in which after a discotic liquid crystal compound is dispersed in a polymeric matrix, a magnetic field is applied thereto slantingly, and a negative uniaxial structure, where an optic axis is tilted from the normal to the substrate, is formed.

As is clear from the above description in the publication, it is assumed that the discotic liquid crystal is an optical material which is expected to improve the optical property, which has not been obtained, and to be applied to the new optical field because of the peculiar orientation form and refractive index due to the molecular shape of the liquid crystal and the peculiar optical feature based on the refractive index.

However, according to the technique described in the above publication, the orientation form and the refractive index structure based on the orientation form are limited to the form and the uniaxial structure which are peculiar to the discotic liquid crystal, and the orientation method should be complicated because in this method, a liquid crystal compound is dispersed in a polymeric matrix, an a magnetic field or an electric field is applied thereto. Therefore, this technique was limited in the aspect of industrial application.

One of the typical utilization of the liquid crystalline optical films is compensating plates of every kind for a liquid crystal display.

Since the liquid crystal display has such features as a low-voltage driving, light weigh and low cost, it is in common use widely as display for a notebook-type personal computer, a portable electronic equipment, a portable television, etc. The liquid crystal display adopts various systems with various orientation form of the liquid crystal and various driving electrodes to be utilized. Particularly, an active matrix-type LCD (Liquid Crystal Display), which is represented by a TFT (Thin Film Transistor)-LCD using TN (Twisted Nematic)-type liquid crystal, is greatly expected as a high-performance display because of its high-speed response and high image quality instead of a cathode-ray tube. However, when the LCD is compared with the cathode-ray tube, it becomes clear that the TFT-LCD has a decisive disadvantage, that is, a viewing angle dependence of display. The viewing angle dependence is a problem that when viewing a display sideways, display performance (contrast ratio and gray scales) is deteriorated. This is caused by utilizing members such as liquid crystal and a deflecting plate having optical anisotropy, and this problem arises generally in the liquid crystal display. However, since the TFT-LCD takes aim at high-quality display, the problem of the viewing angle dependence is more serious to the TFT-LCD than to another display systems. For instance, as to a liquid crystal television which is one of the important applications of the TFT-LCD, even a slight change in colors and in contrast due to the viewing angle displease people. Moreover, in the case where an area is made larger, since the viewing angle changes with a position of the screen, there arises such a problem that display of constant quality cannot be obtained between the central por-

tion and the edge portion of the screen.

The compensating plate for the LCD display which is provided conventionally has an insufficient viewing angle, and thus further improvement is desired.

OBJECT OF THE INVENTION

An object of the present invention is to provide a novel liquid crystalline optical film which gets out of the scope of the orientation form and the refractive index structure of the conventional discotic liquid crystal, and more specifically, to provide a liquid crystalline optical film, which is obtained by, in particular, uniform hybrid orientation and stabilization of discotic liquid crystal over a large area, and which is obtained by an industrially easy method.

Another object of the present invention is to provide a compensating film for a liquid crystal display element which is capable of enlarging a viewing angle as a compensator for a liquid crystal display.

The present invention solves the above problems and provides a compensating film for a liquid crystal display element which is capable of enlarging a viewing angle as a compensating plate especially for a TN liquid crystal display which is driven by a normally white mode with either a rotatory mode or a birefringence mode.

A main object of the present invention is to provide a liquid crystal display into which a compensating film is incorporated.

Still another object of the present invention is clarified by the following description.

SUMMARY OF THE INVENTION

The present invention, in the first aspect thereof, relates to a liquid crystalline optical film formed by a single-layered film of a discotic liquid crystalline material having a fixed orientation form of a discotic liquid crystal. The orientation form is a hybrid orientation in which the angle between discotic crystal directors near the upper interface of the film and a film plane is different from the angle between discotic crystal directors near the lower interface of the film and the film plane.

The present invention, in the second aspect thereof, relates to the above first liquid crystalline optical film wherein the hybrid orientation is such that on one side of the film discotic liquid crystal directors are at an angle of between 60° and 90° relative to the film plane, while on the other side of the film discotic liquid crystal directors are at an angle of between 0° and 50° relative to the film plane.

The present invention, in the third aspect thereof, relates to the above first or second liquid crystalline optical film formed on a substrate.

The present invention, in the fourth aspect, relates to a liquid crystal display element compensating film formed by the above first or second liquid crystalline optical film.

The present invention, in the fifth aspect thereof, relates to the above fourth liquid crystal display element compensating film formed by at least one sheet of the above fourth compensating film being used for a liquid crystal element employing a normally white mode provided with a TN liquid crystal cell and with a pair of upper and lower polarizing plates sandwiching the liquid crystal cell.

The present invention, in the sixth aspect thereof, relates to the above fourth liquid crystal display element compensating film at least one sheet of which is used on one or both sides of the TN liquid crystal cell and is between a pair of upper and lower polarizers sandwiching the TN liquid crystal cell.

The present invention, in the seventh aspect thereof, relates to a liquid crystal display element compensating film is a compensating film used for a birefringence mode and normally white mode liquid crystal display element having a TN liquid crystal cell and a pair of polarizing plates in which transmission axes intersect perpendicularly to each other. The compensating film is formed by the above first or second liquid crystalline optical film.

The present invention, in the eighth aspect thereof, relates to a liquid crystal display element compensating film is a compensating film used for a rotatory mode and normally white mode liquid crystal display element having a TN liquid crystal cell and a pair of polarizing plates in which transmission axes intersect perpendicularly to each other. The compensating film is formed by a single-layered film of a discotic liquid crystalline material having a fixed orientation form of a discotic liquid crystal, and the orientation form is a hybrid orientation in which the angle between discotic crystal directors near the upper interface of the film and a film plane is different from the angle between discotic crystal directors near the lower interface of the film and the film plane.

The present invention, in the ninth aspect thereof, relates to a liquid crystal display incorporating therein at least one sheet of the above eighth liquid crystal display element compensating film.

The present invention, in the tenth aspect thereof, relates to an optical element comprising at least the above first or second liquid crystalline optical film described and a substrate and wherein the angle between discotic liquid crystal directors in the vicinity of the film interface on the substrate side and the film plane is in the range of 0° to 50°.

The present invention, in the eleventh aspect thereof, relates to an optical element comprising a substrate and the above first or second liquid crystalline optical film. The substrate substantially has no anchoring effect for the discotic

liquid crystal.

The present invention, in the twelfth aspect thereof, relates to an optical element comprising a substrate not having an alignment film and the above first or second compensating film.

The present invention, in the thirteenth aspect thereof, relates to a compensating element comprising the above tenth, eleventh or twelfth optical element.

The present invention, in the fourteenth aspect thereof, relates to a liquid crystal display incorporating therein at least one sheet of the above thirteenth compensating element.

The following describes the present invention in detail.

In general, the discotic liquid crystal is developed by molecules each having a disc-like mesogen of high flatness. The discotic liquid crystal is characterized in that the refractive index in a very small area in the liquid crystal layer has a negative uniaxial property. As shown in Fig. 1, if refractive indexes in a certain plane are equal (assumed to be "no"), the direction perpendicular to the plane is a director (a unit vector representing a local orientation direction of liquid crystal). The refractive index in the director direction is assumed to be "ne". There exists the relation of no>ne. The refractive index characteristic and hence optical characteristics of the resulting structure are determined depending on how the director in a very small area is arranged in the whole liquid crystal layer. When the director direction (angle) is the same throughout the whole of the liquid crystal layer, the direction corresponds to the optic axis of the entire liquid crystal layer.

Usually, when directors face in the same direction throughout the whole of a discotic liquid crystal layer, the liquid crystal layer exhibits a negative uniaxial property. An orientation of a discotic liquid crystal obtained by a conventional method gives the negative uniaxial structure as shown in Fig. 2(a) and 2(b). The orientation shown in Fig. 2(a) is called a homeotropic orientation because all of discotic liquid crystal directors present in the liquid crystal layer are arranged in the normal to the substrate. The optic axis of the liquid crystal layer where this orientation was formed presents in a direction of the normal of the substrate. Moreover, the orientation shown in Fig. 2(b) is a tilt orientation wherein all of discotic liquid crystal directors present in the liquid crystal layer are tilted at a certain angle from the normal of the substrate. In the tilt orientation, an optic axis of the entire liquid crystal layer presents in the direction in which the directors are tilted (tilt angle direction).

The orientation form of the optical film according to the present invention is entirely different from the above-mentioned negative uniaxial structure including the homeotropic orientation and tilt orientation. The optical film according to the present invention is a single-layer film wherein an optic axis of the entire film is not existent and wherein the angle between discotic liquid crystal directors and the film plane is different between the portion near the upper interface of the film and the portion near the lower interface of the film. More particularly, the angle between the directors and the film plane is different at various portion in the film thickness direction. In the optical film according to the present invention, moreover, the directions obtained when the directors are projected in the film plane (director directions) are almost the same throughout the entire liquid crystal layer, namely, throughout the compensating film. Now that the director angle is different between the portion near the upper interface of the film and the portion near the lower interface of the film and that the director directions face in one direction, the optical film is presumed to present a unique orientation such that the angle between the discotic liquid crystal directors and the film plane varies almost continuously in the film thickness direction, as shown in Fig. 2(c).

In a rod-like nematic liquid crystal, the orientation which presents such a continuous change in the director angle in the film thickness direction is called a hybrid orientation. In view of this point, the orientation form of the optical film according to the present invention will also be designated hybrid orientation hereinafter.

In the present invention, an angle range of the hybrid orientation in the film thickness direction is usually between 60° and 90° in the vicinity of the upper interface of the lower interface of the film and between 0° and 50° in the vicinity of the opposite interface in terms of an absolute value of a minimum angle between the discotic liquid crystal director and the film plane, namely, an angle obtained by (90° - a°) wherein "a" is an angle between the discotic liquid crystal director and the normal line to the film plane which is not an obtuse angle (i.e. within the range of from 0° to 90°). More preferably, the absolute value of one angle is between 80° and 90° and that of the other angle is between 0° and 30°.

Here; the portions near the interfaces means a depth for about 1% to 5% of the film thickness from the surface of the film towards the film thickness direction.

As mentioned above, since the liquid crystalline optical film according to the present invention at least exhibits the hybrid orientation where the angle between the discotic liquid crystal directors and the film plane is different between the portion near the upper interface and the portion near the lower interface, the directors faces are different in the thickness direction, and thus from view of a structure as the film, the optic axis does not present any longer and the uniaxial property is lost. When a light is let pass through the liquid crystal having such an orientation form, complicated birefringence which has not been obtained can be observed.

Now, a description will be given of the discotic liquid crystalline material used in the present invention. The said material is constituted by a discotic liquid crystalline material alone or a composition containing at least one such liquid crystalline compound.

By C. Destrade et al. discotic liquid crystals are classified according to their molecular orientation orders into ND phase (discotic nematic), Dhd phase (hexagonal ordered columnar phase), Dhd phase (hexagonal disordered columnar phase), Drd phase (rectangular disordered columnar phase), and Dob phase (oblique columnar phase) [C. Destrade et al. Mol. Cryst. Liq. Cryst. 106, 121 (1984)]. The molecular orientation order is not specially limited in the present invention, but from the standpoint of easiness of orientation it is preferable to use a material having at least ND phase which is the lowest in orientation order. Particularly preferred is a material which has ND phase alone as the only liquid crystal phase.

The discotic liquid crystalline material used in the present invention preferably does not exhibit transition from liquid crystal phase to crystal phase at the time of fixing its orientation form so that the orientation form in the state of liquid crystal may be fixed without impairment. Moreover, it is desirable that the discotic liquid crystalline material when formed into film can maintain the orientation form under the conditions of practical use and can be handled in the same manner as a solid. Most typically and preferably, the "fixed" state as referred to herein indicates an amorphous glassy state in which the liquid crystal orientation in the liquid crystal state is frozen. However, no limitation is placed thereon. That is, the fixed state in question indicates a state in which under the conditions of practical use of the liquid crystalline optical film of the present invention, more specifically in the temperature range usually from 0°C to 50°C, more severely from -30°C to 70°C, the fixed orientation form can be retained stably without fluidity of the film and without a change in the orientation form caused by an external field or force. In view of the above points, it is preferable that the discotic liquid crystalline material used in the present invention possesses any of the following properties.

1) At a lower temperature region than the state of liquid crystalline material has only a glassy state and does not have a crystalline phase. As the temperature drops from the state of liquid crystal, the material is fixed into the glassy state.

2) The material has a crystalline phase at a lower temperature region than the state of liquid crystal and has a glassy state at a lower temperature region than the crystalline phase. As the temperature drops from the state of liquid crystal, a crystal phase does not appear (due to supercooling of crystal phase or due to monotropicity involving crystallization only during the rise of temperature), but the material is fixed into the glassy state.

3) The material has a crystal phase at a lower temperature region than the state of the liquid crystal, but at a still lower temperature region the material does not exhibit a clear glass transition, and when the temperature drops from the state of liquid crystal, there does not appear a crystalline phase (due to supercooling of crystalline phase or due to monotropicity involving crystallization only during the rise of temperature). At a still lower temperature than the melting point, which is observed upon re-heating after fixing, the material is extremely limited in its molecular fluidity and can be regarded as a solid material in practical use.

4) At a lower temperature region than the state of liquid crystal a clear transition to crystal phase or to glassy state is observed neither during the rise of temperature nor during the fall of temperature. There is no fluidity in the working temperature range of the film in question, and even when an external force such as shear or an external field is applied to the film, the orientation form does not change.

Of the above properties, more preferable ones are 1) and 2), and the most preferred is 1). Also as to 3) and 4), both properties are applicable to practical use without any trouble, provided it is necessary to make sure carefully that there will be no possibility of occurrence of orientation disorder under the working conditions of practical use of the film. More specifically, usually in the temperature range from 0°C to 50°C, if the orientation form is not disordered under force application of shear for example, there is no problem. On the other hand, if the orientation form is disordered due to shear for example, the inherent optical performance is lost, and no matter what treatment may be conducted subsequently, it is difficult to restore the original orientation form, thus posing a serious problem in practical use.

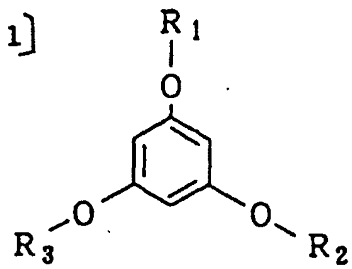
It is desirable that the discotic liquid crystalline material used in the present invention possess any of the foregoing properties and exhibit a good domain uniformity due to uniform and satisfactory orientation. If the domain uniformity is bad, the resulting structure will be a polydomain structure, in which light is scattered due to an orientation defect at the boundary of domains. Deterioration in the transmittance of the film will also result. Thus, a poor domain uniformity is not desirable.

Description is now directed to discotic liquid crystalline compounds each employable as the liquid crystalline material in question. These compounds are each composed principally of a disc-shaped central portion (discogen) essential for developing a discotic liquid crystal phase and substituent groups necessary for stabilizing the liquid crystal phase. Monofunctional ones are preferred as the said substituent groups, but even a compound obtained by using bifunctional substituent groups and partially coupling discogens with each other, allowing oligomerization or polymerization to take place, is also employable preferably as the liquid crystalline material in the present invention.

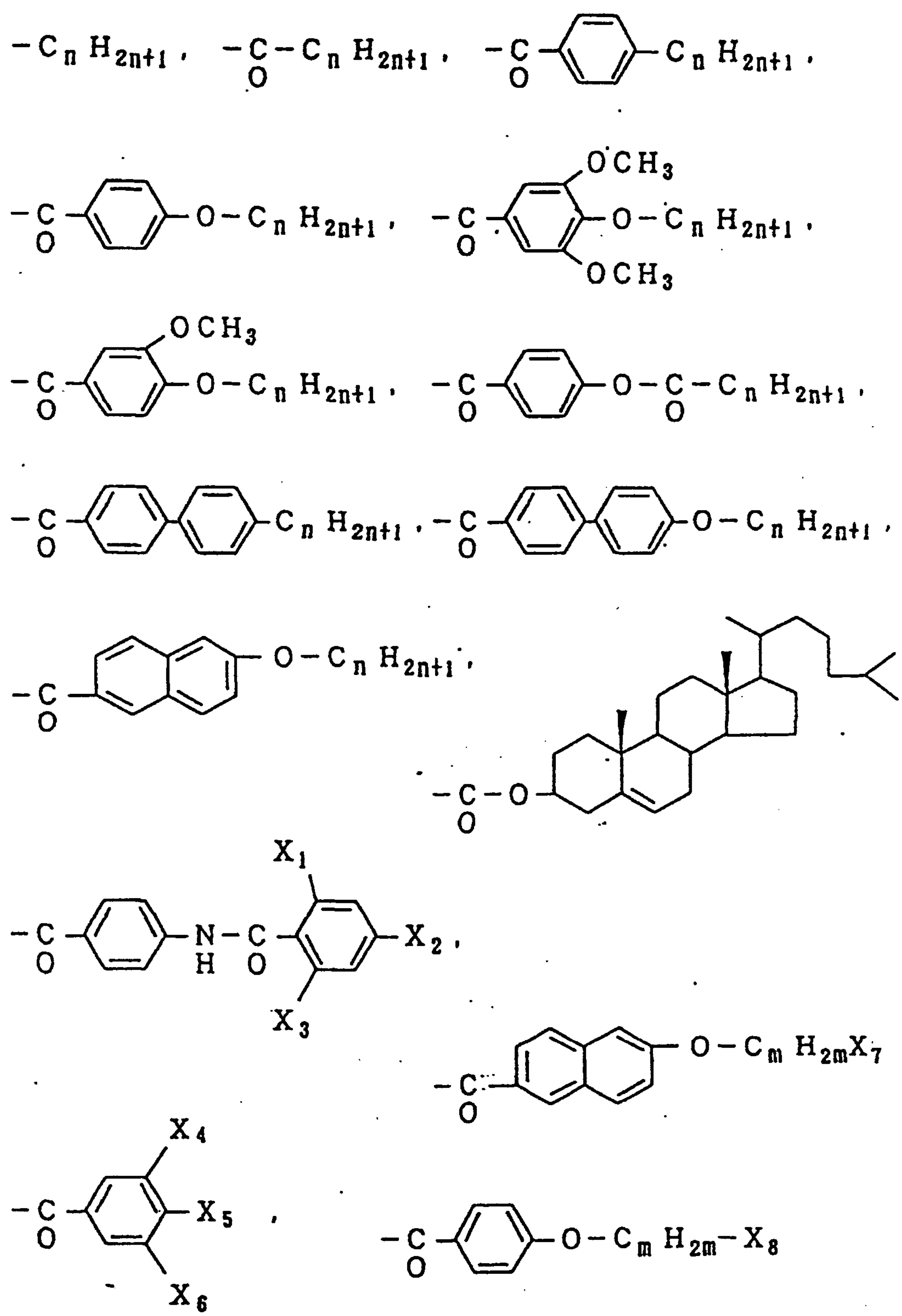
The following are molecular structures of discotic liquid crystalline compounds employable in the present invention:

Hereinafter, the molecule structures of the discotic liquid crystalline compounds used in the present invention are illustrated concretely:

[Structural formula 1]



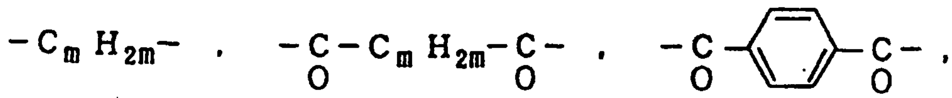
wherein R_1, R_2 and R_3 are each independently a monofunctional or bifunctional substituent group selected from the following groups:
Monofunctional substituent groups:

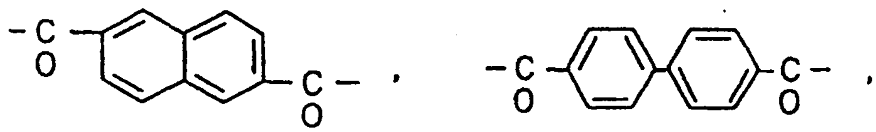


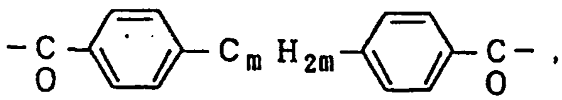
etc.

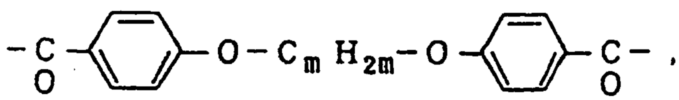
wherein C_nH_{2n+1} is a linear or branched alkyl group, and n is an integer of 1-18, preferably 3-14, X_1-X_8 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, $C_\ell H_{2\ell+1}$ is a linear or branched alkyl groups, ℓ is an integer of 1-18, preferably 1-10, C_mH_{2m} is a linear or branched alkylene chain and m is an integer of 1-6, preferably 2-10.

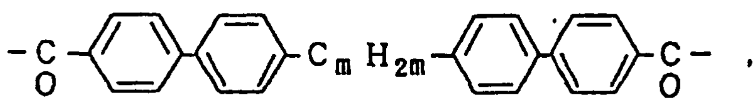
Bifunctional substituent groups:

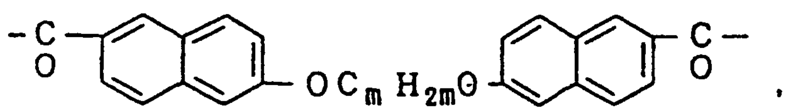


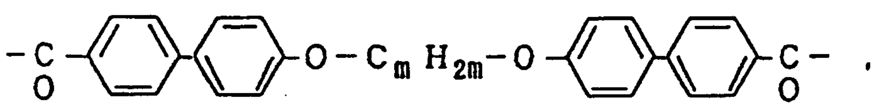


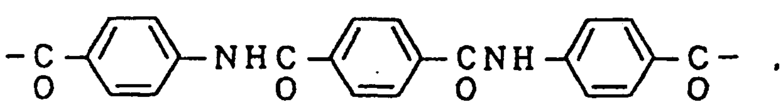


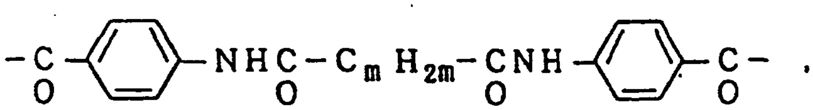


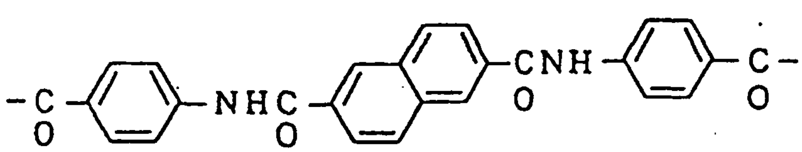






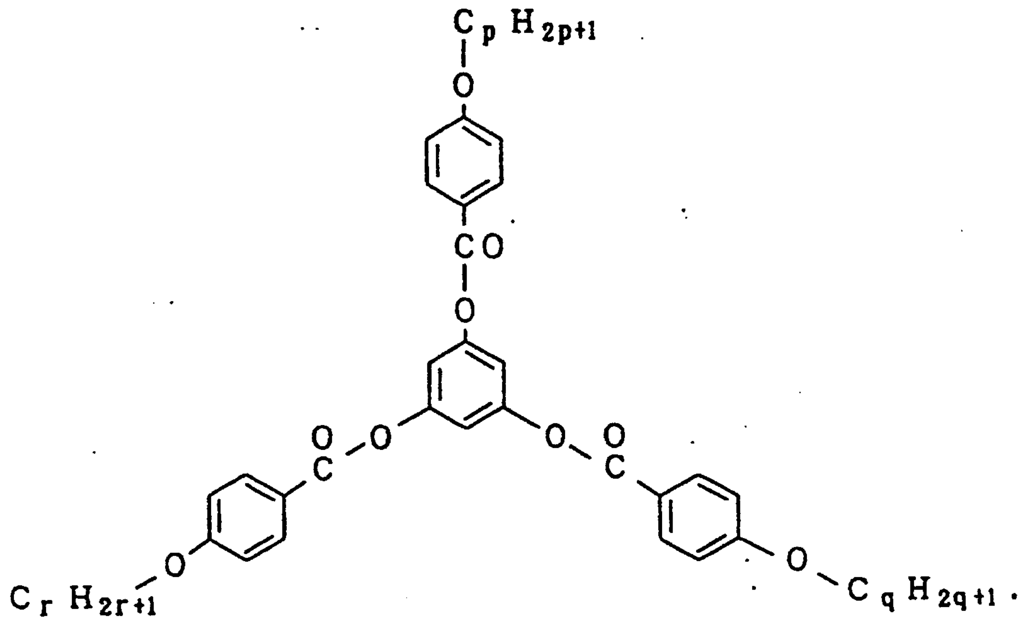




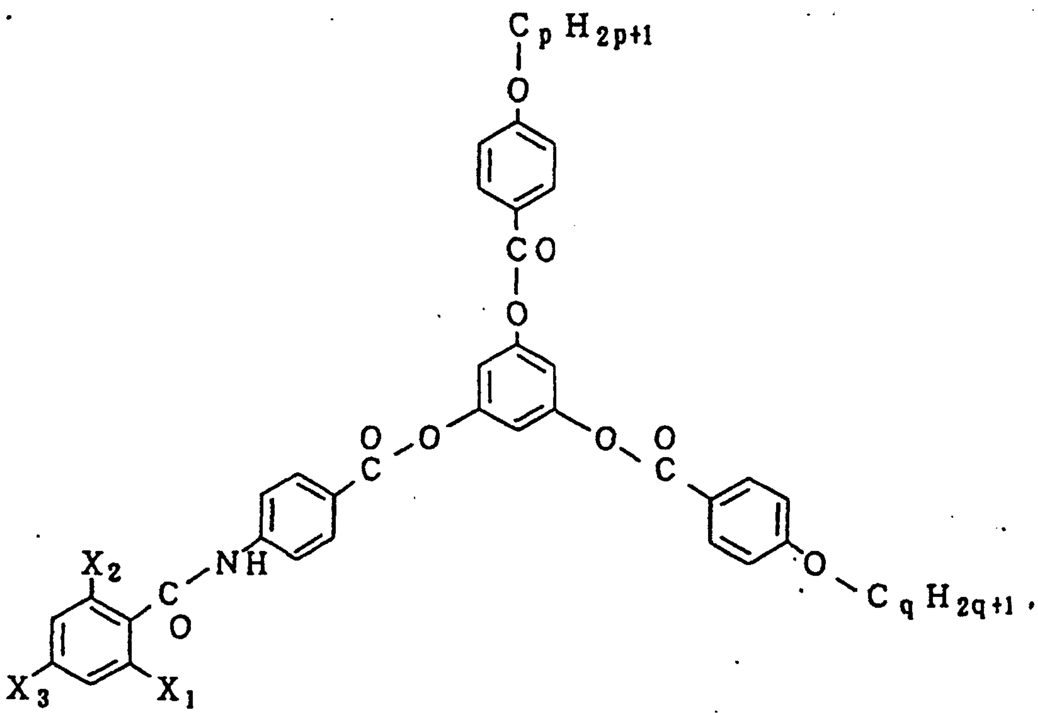


etc.

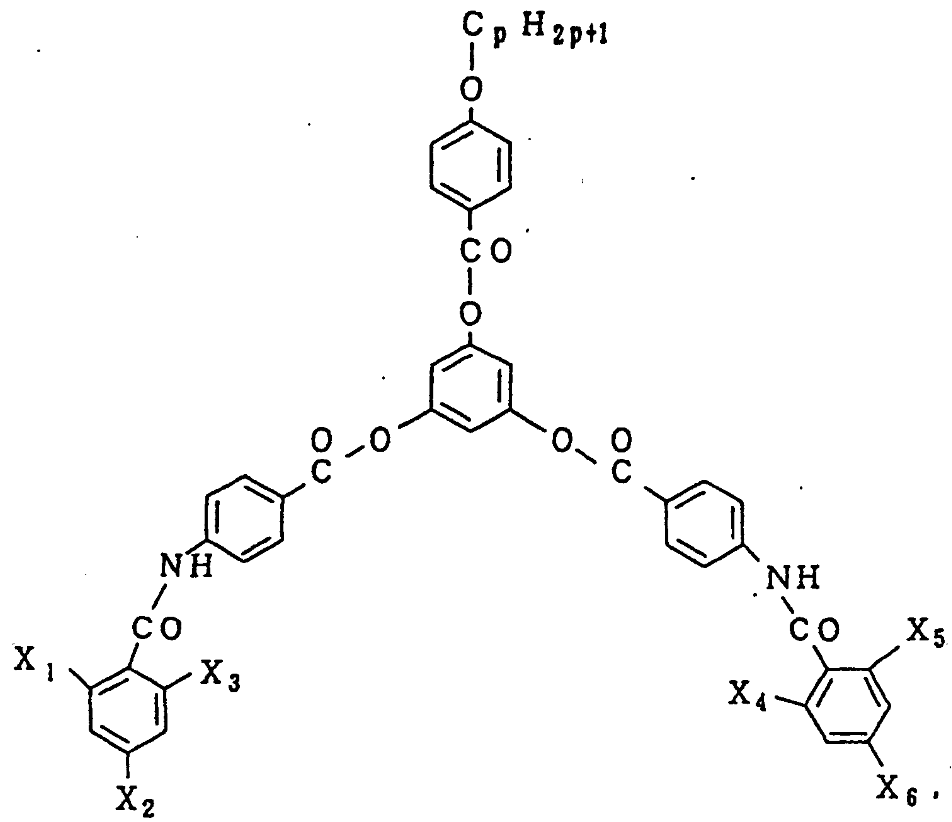
wherein C_mH_{2m} is a linear or branched alkylene chain, and m is an integer of 2-16, more preferably 4-12. Examples of the concrete structures:



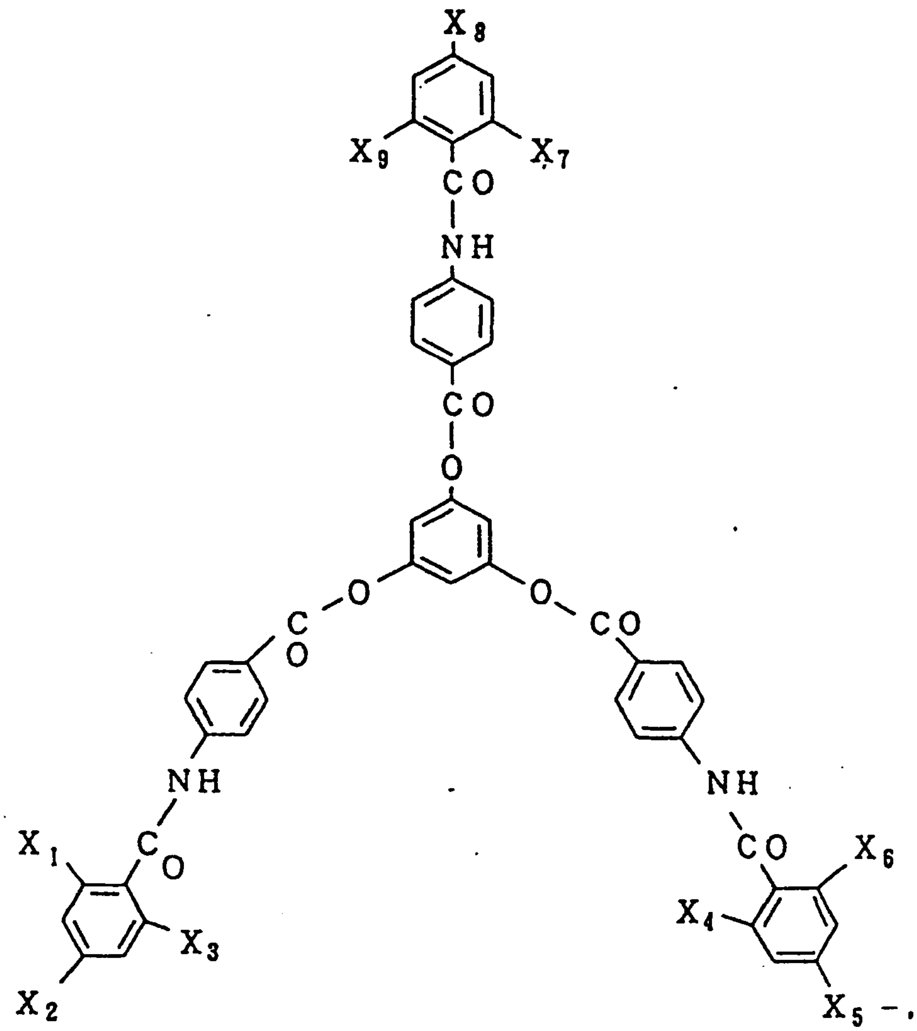
wherein p, q and r are each an integer of 1-18, preferably 3-14.



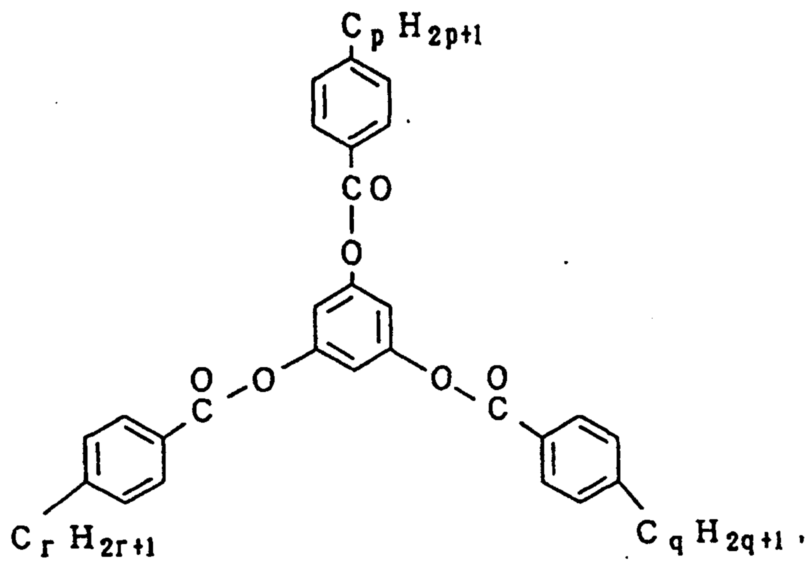
wherein p and q are each an integer of 1-18, preferably 3-14, X_1, X_2 and X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



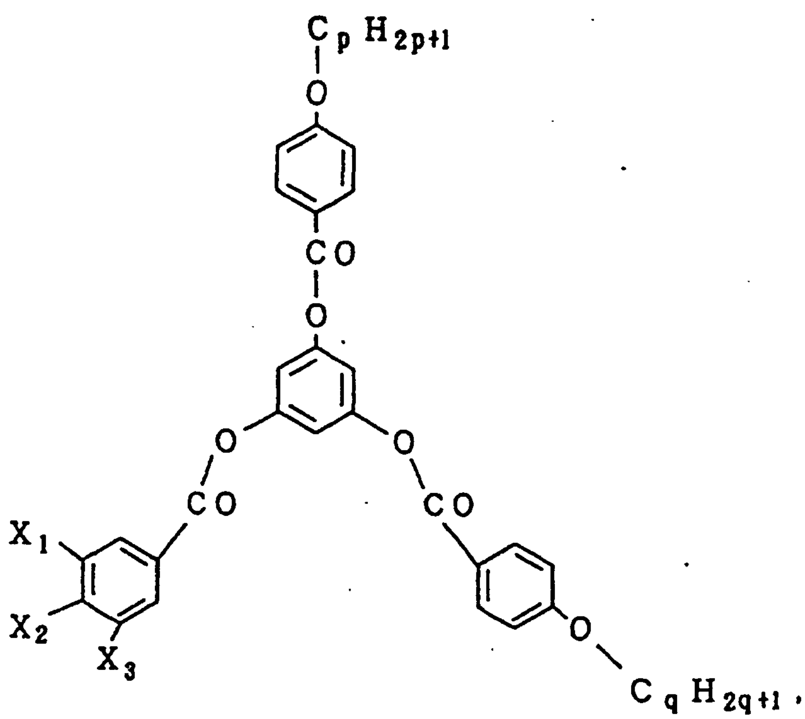
wherein p is an integer of 1-18, preferably 3-14, X_1-X_6 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl, and ℓ is an integer of 1-18, preferably 1-10.



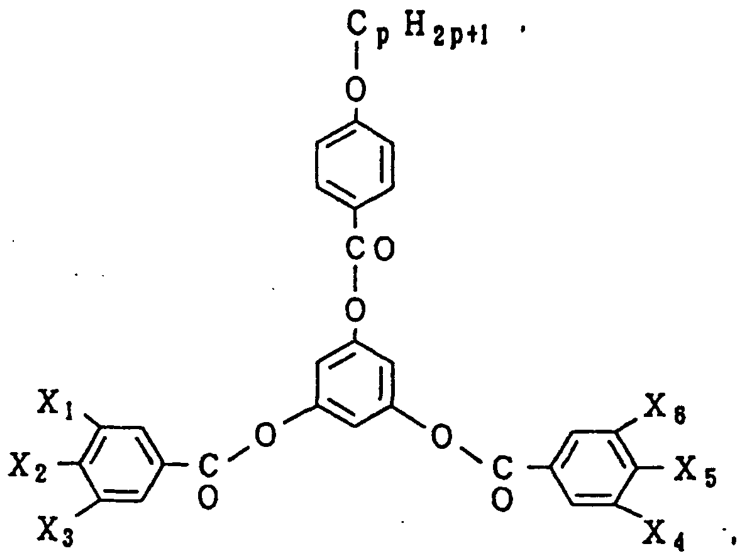
wherein X_1-X_9 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



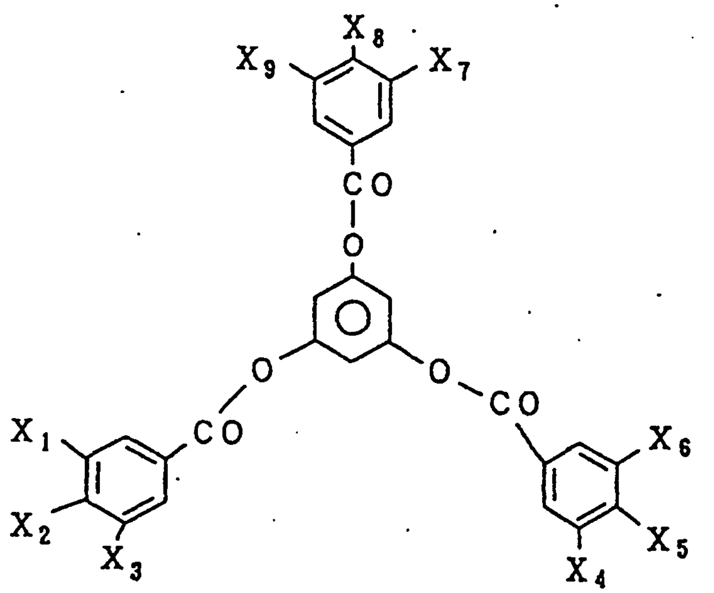
wherein p, q and r are each an integer of 1-18, preferably 3-14.



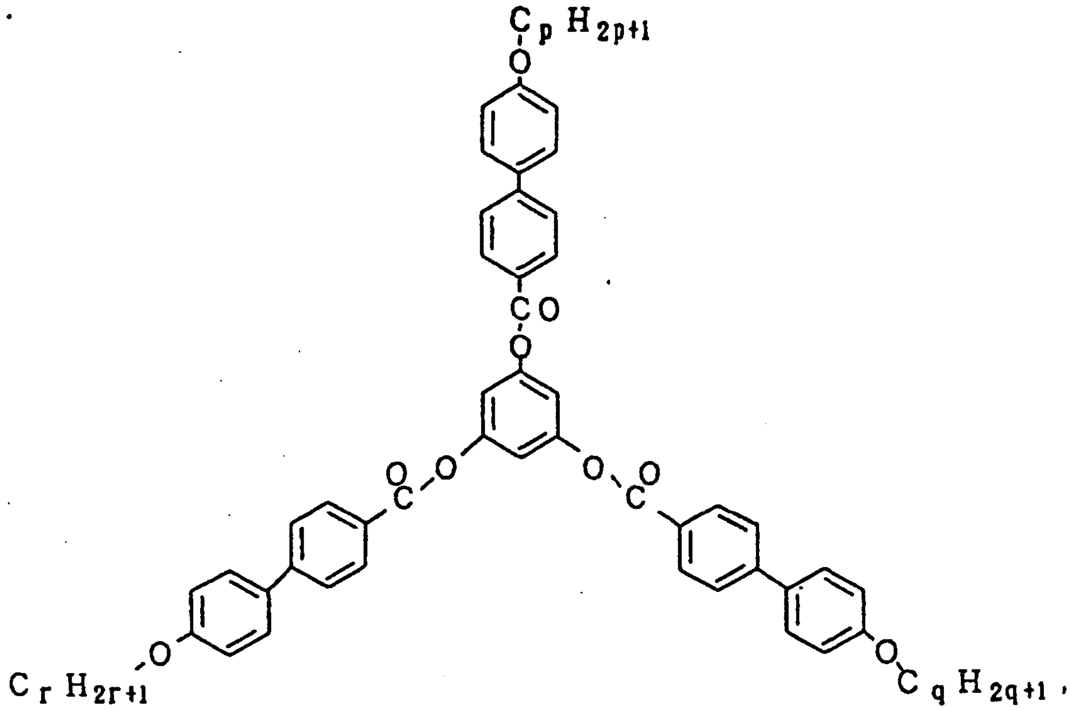
wherein p, q are each an integer of 1-18, preferably 3-14. X_1 and X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



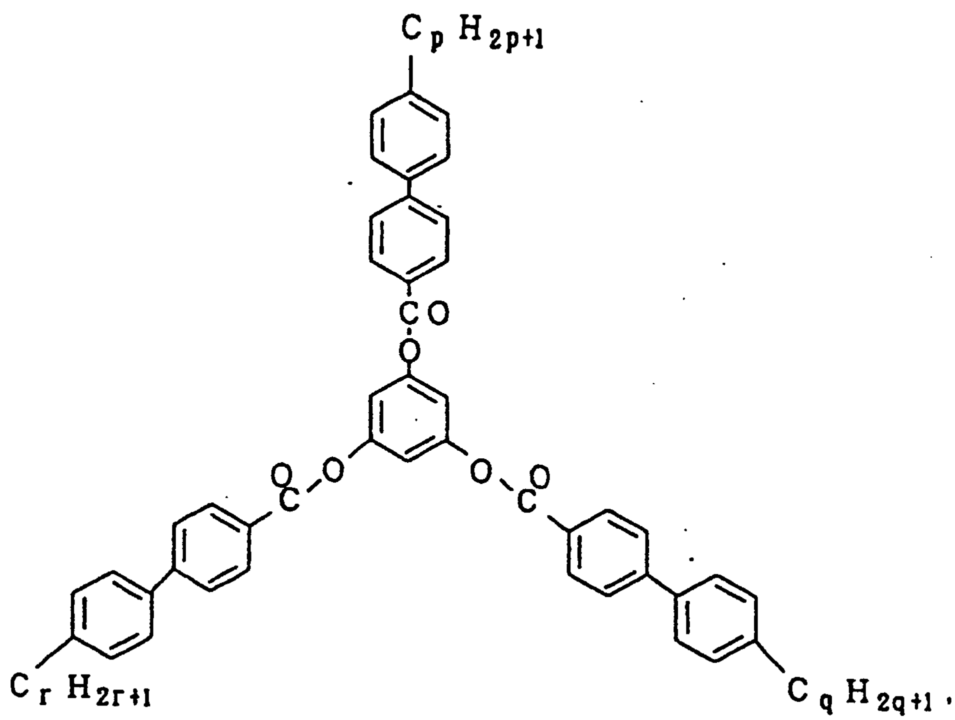
wherein p is an integer of 1-18, preferably 3-14, X_1-X_6 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



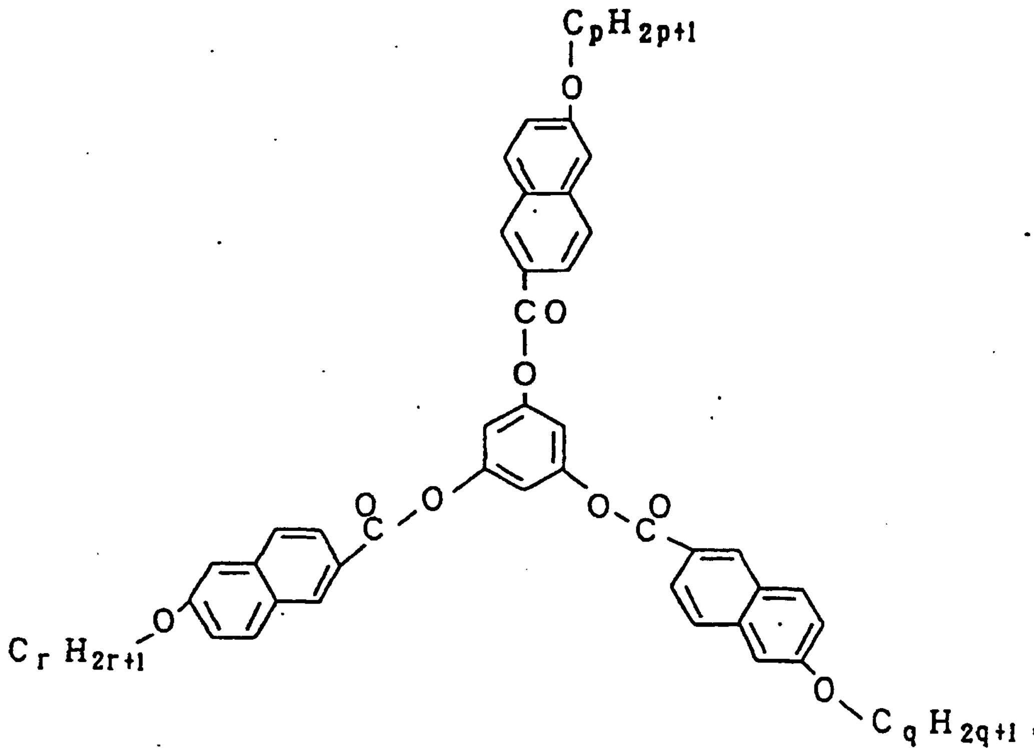
wherein X_1-X_9 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



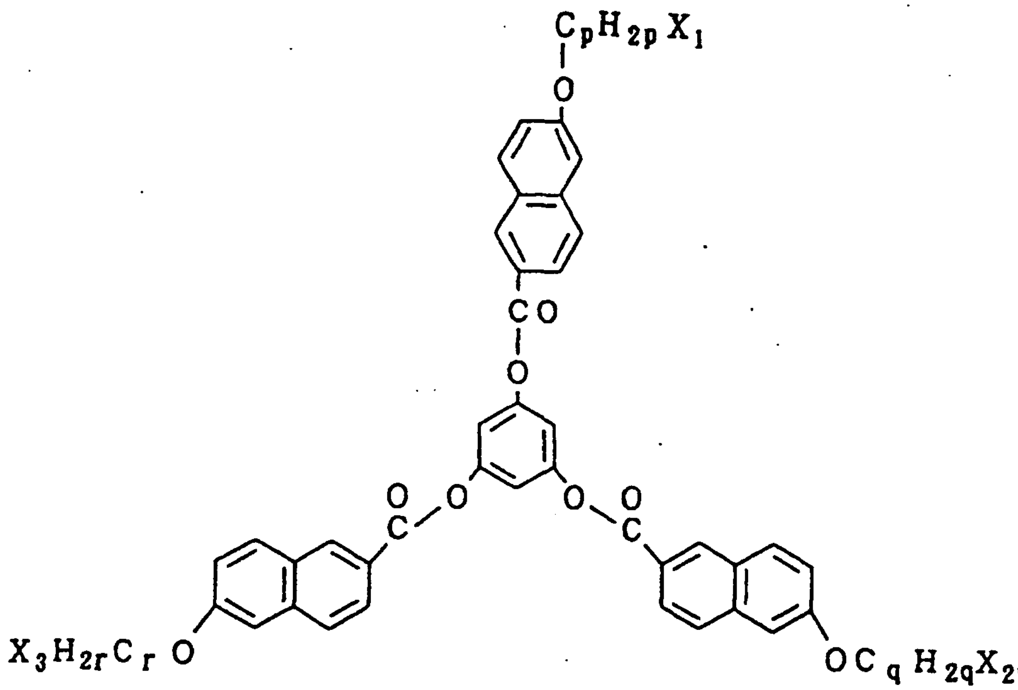
wherein p, q and r are each an integer of 1-18, preferably 3-14.

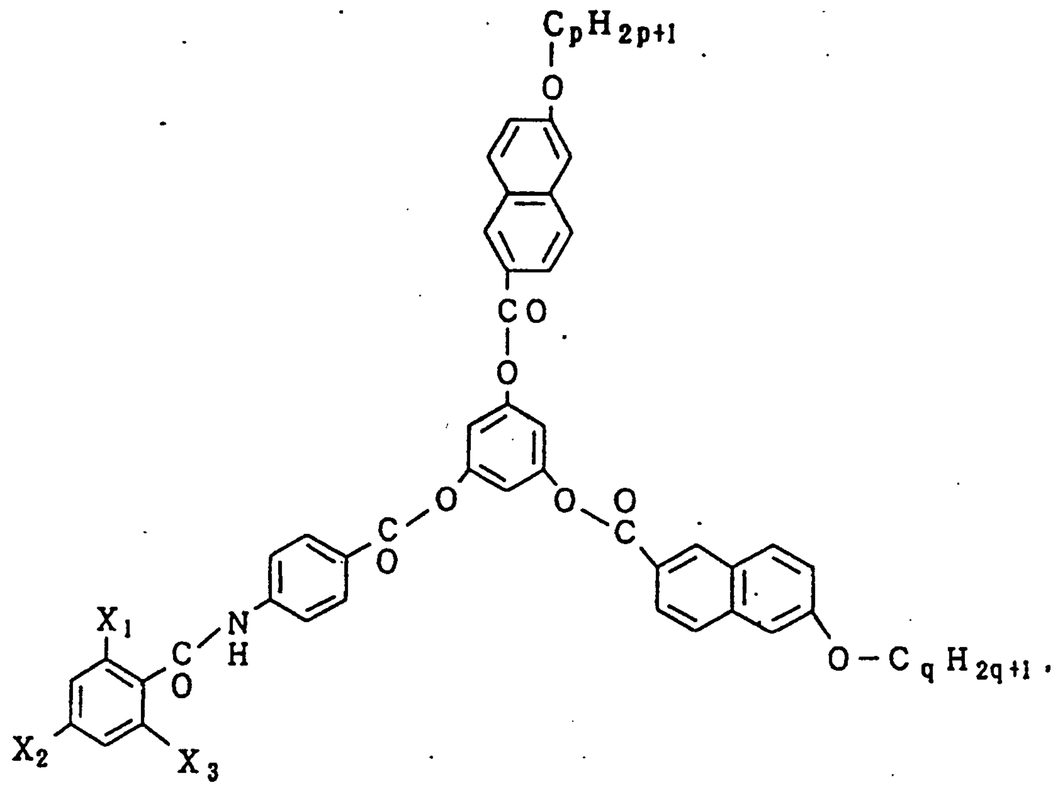


wherein p, q and r are each an integer of 1-18, preferably 3-14.

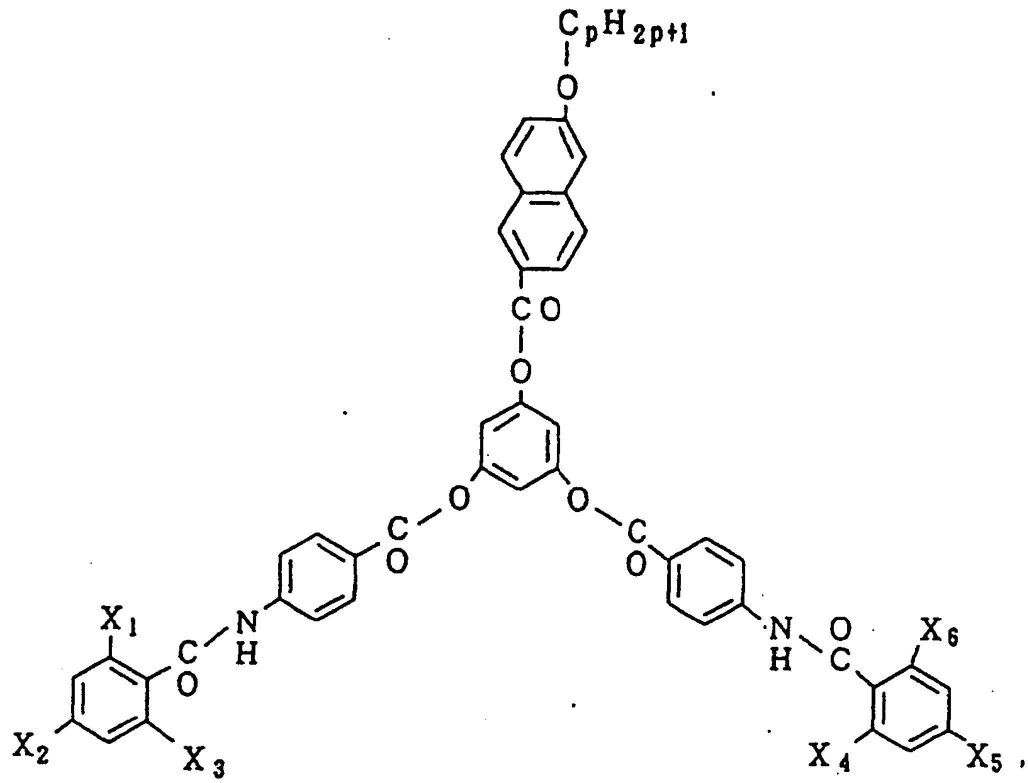


wherein p, q and r are each an integer of 1-18, preferably 3-14.



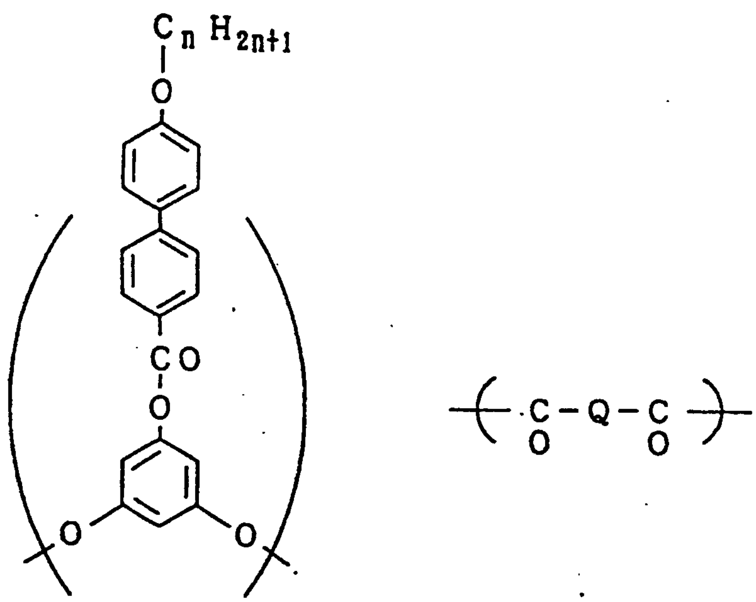


wherein p and q are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

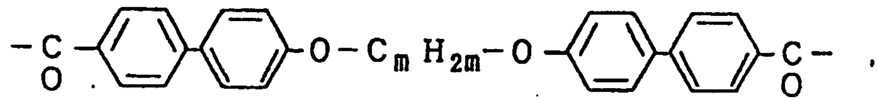


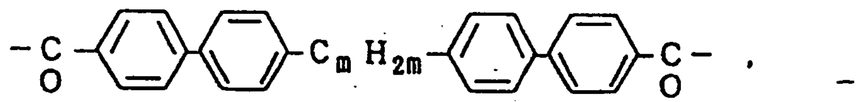
wherein p is an integer of 1-18, preferably 3-14, X_1-X_6 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

Polymer represented by



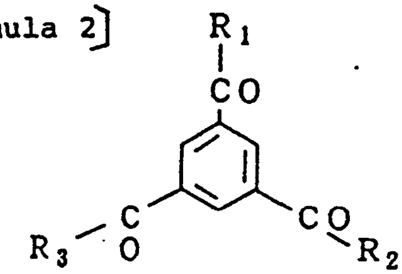
wherein Q is





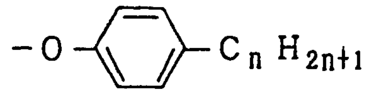
wherein n is an integer of 1-18, preferably 3-14, m is an integer of 2-16, more preferably 4-12 and the average molecular weight is 4,000 - 100,000.

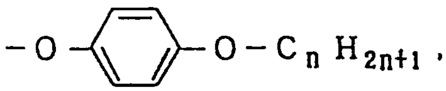
[Structural formula 2]

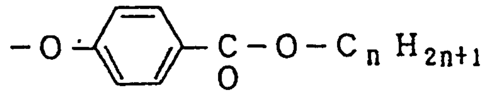


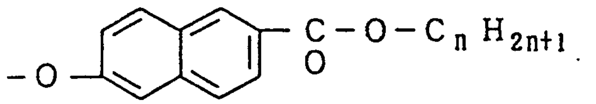
wherein R_1, R_2 and R_3 are each a monofunctional or bifunctional substituent group.
Monofunctional groups:

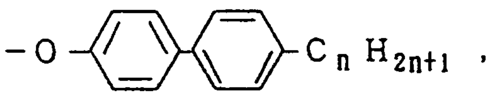
$-O-C_nH_{2n+1}$,

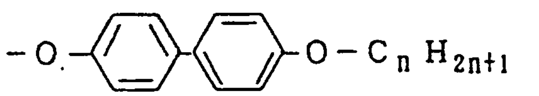


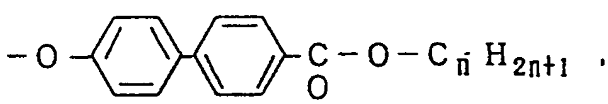


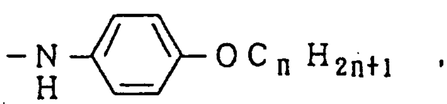


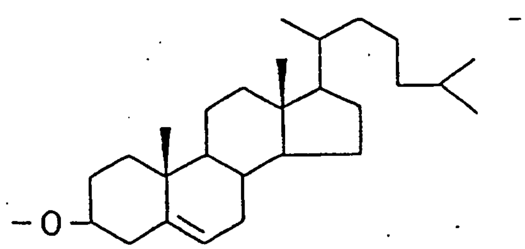








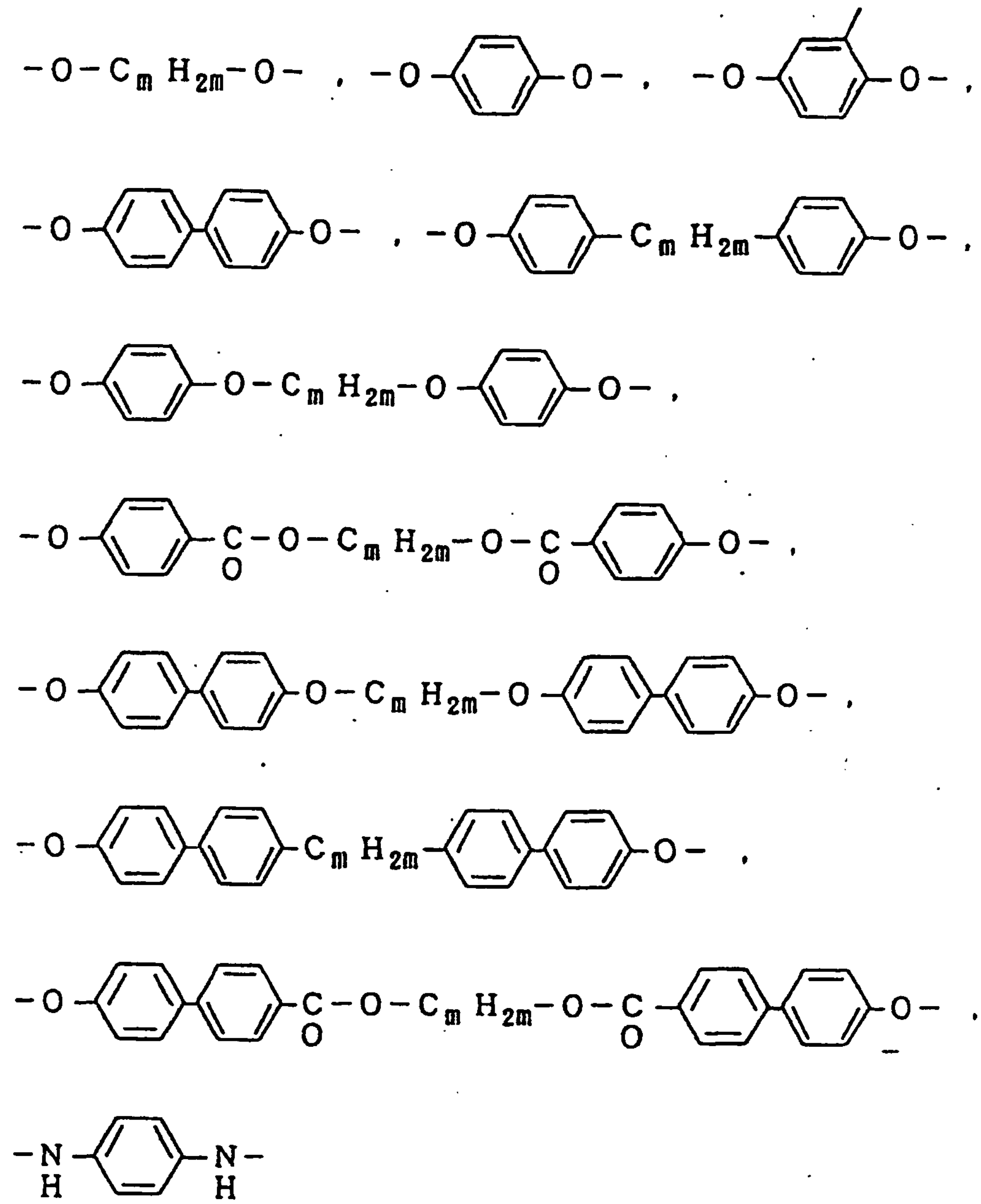




etc.

wherein C_nH_{2n+1} is a linear or branched alkyl gorup, and n is an integer of 1-18, preferably 3-14.

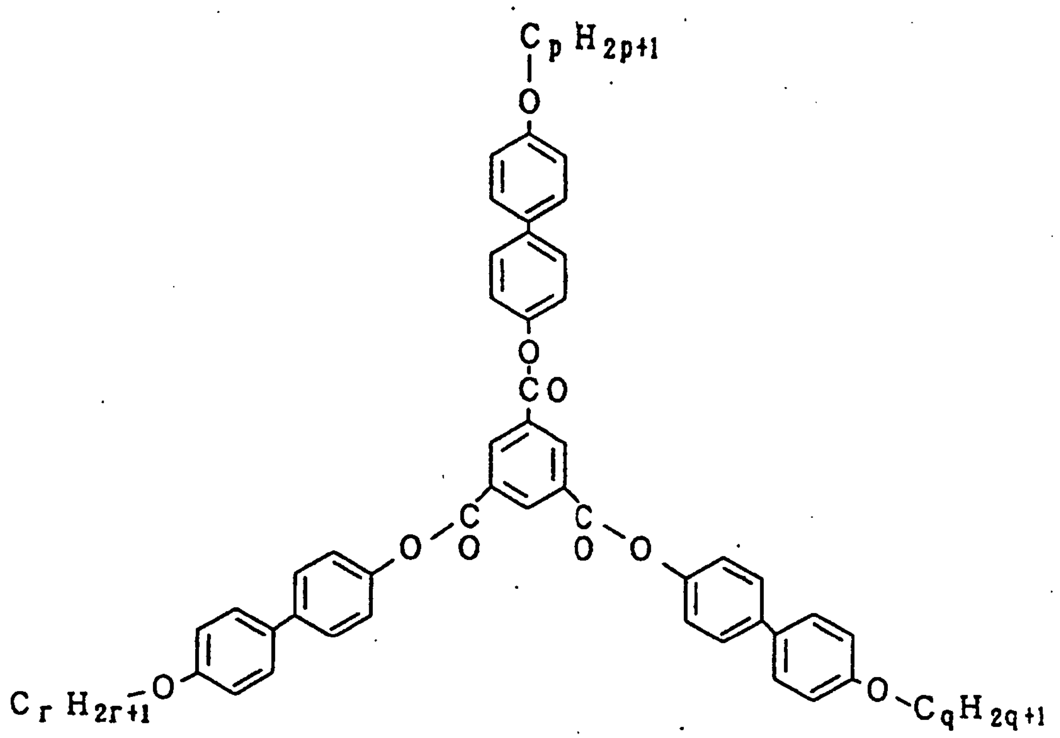
Bifunctional groups:



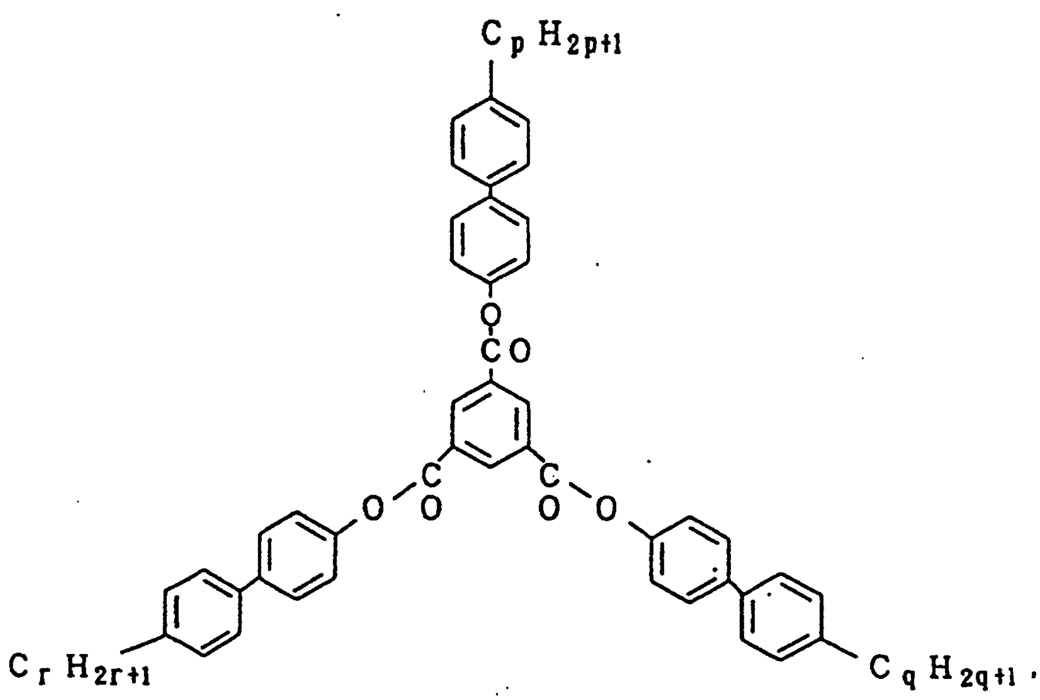
etc.

wherein C_mH_{2m} is a linear or branched alkylene chain, and m is an integer of 2-16, preferably 4-12.

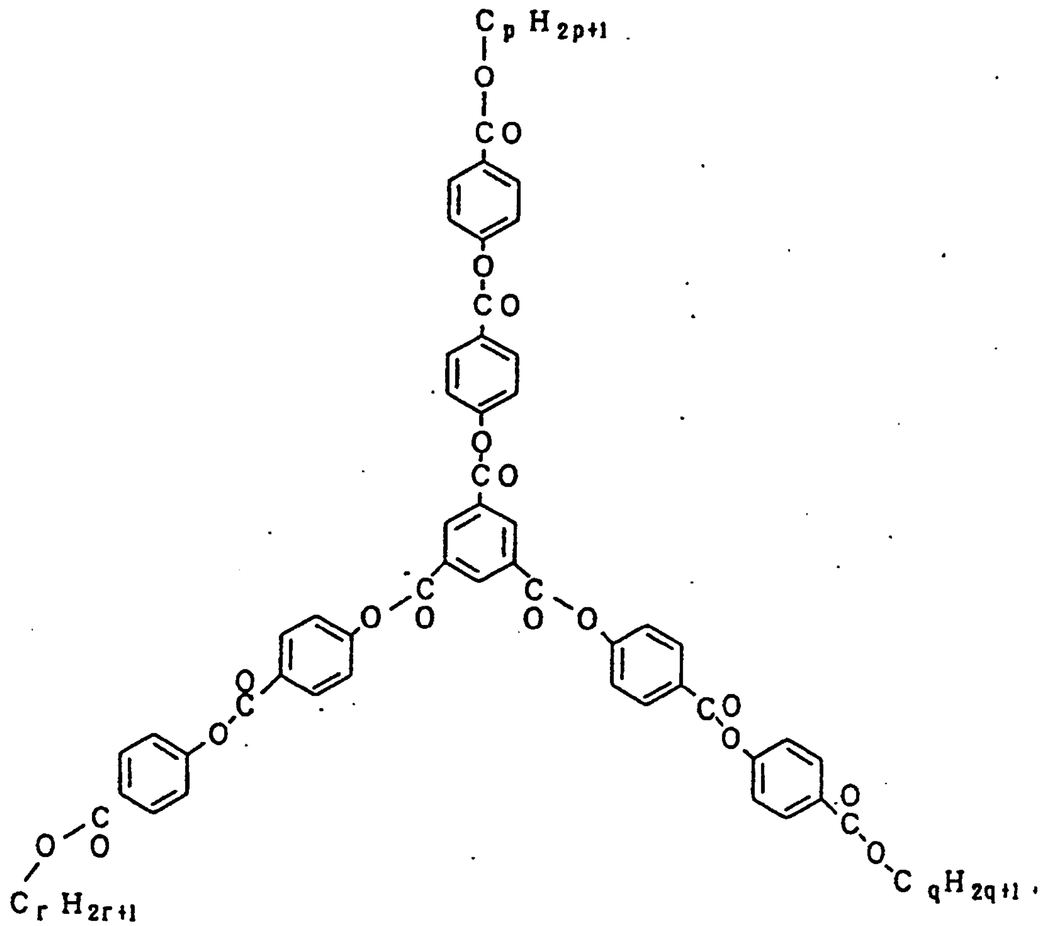
Examples of the concrete structures:



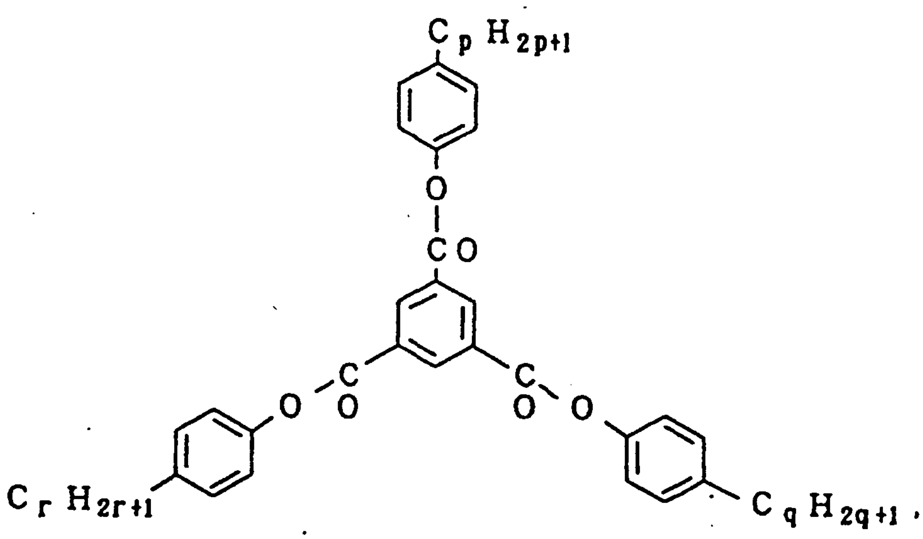
wherein p, q and r are each an integer of 1-18, preferably 3-14.



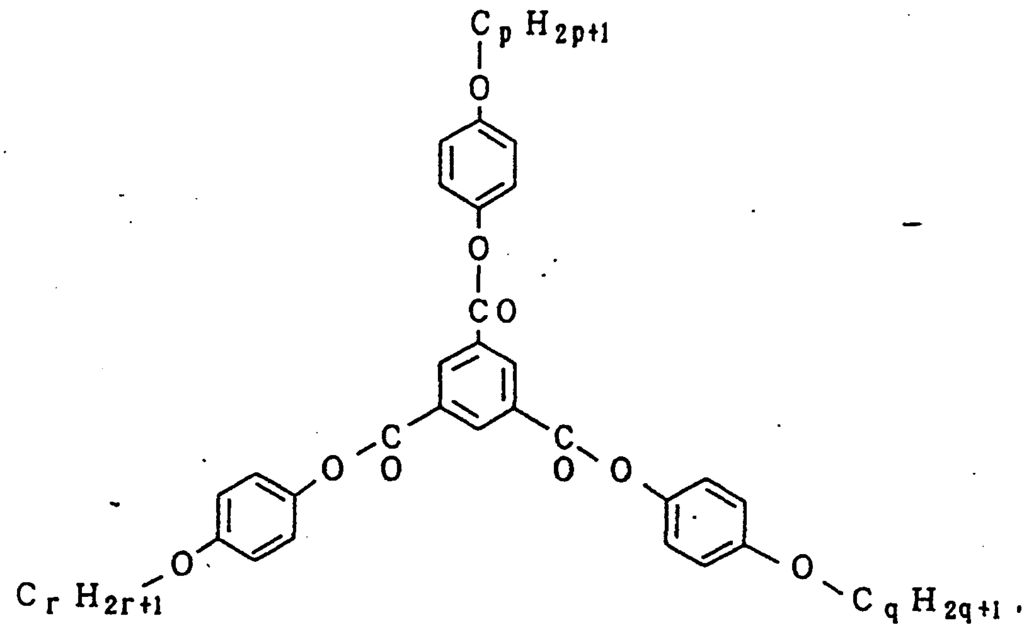
wherein p, q and r are each an integer of 1-18, preferably 3-14.



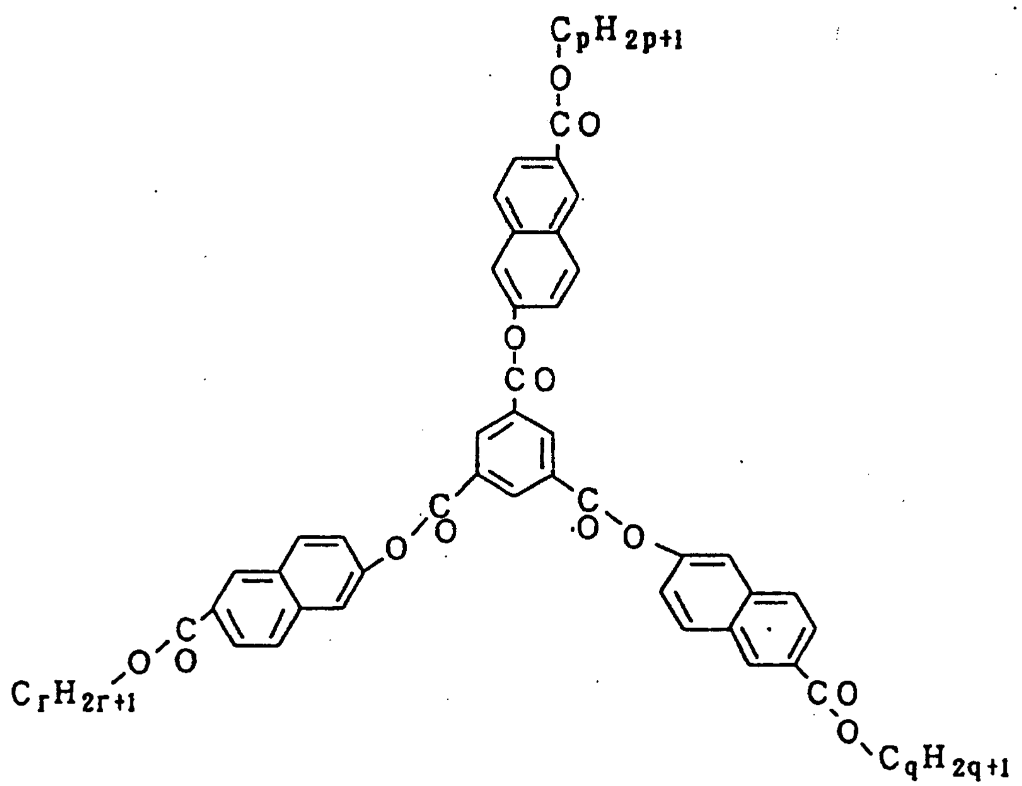
wherein p, q and r are each an integer of 1-18, preferably 3-14.



wherein p, q and r are each an integer of 1-18, preferably 3-14.

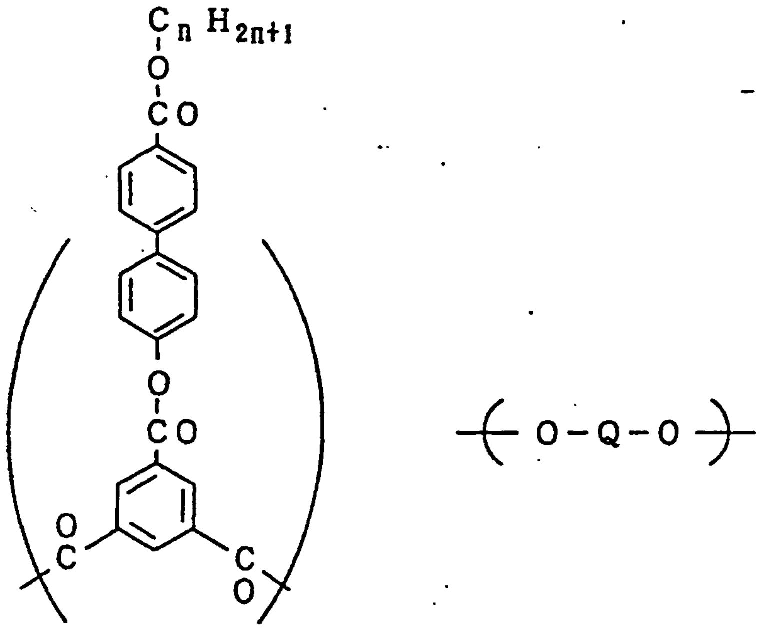


wherein p, q and r are each an integer of 1-18, preferably 3-14.

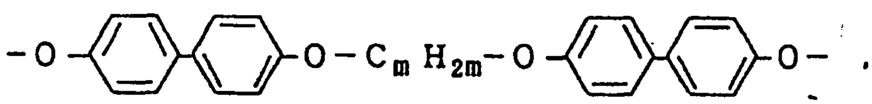


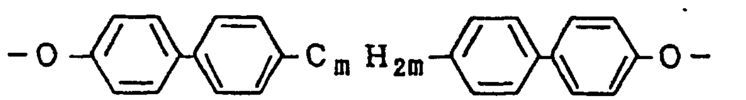
wherein p, q and r are each an integer of 1-18, preferably 3-14.

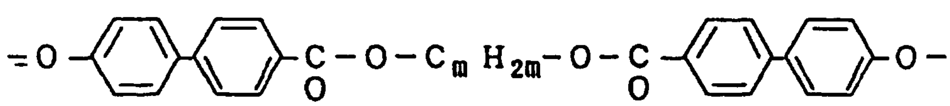
Polymer represented by



wherein the average molecular weight is 4,000 - 100,000 and Q is



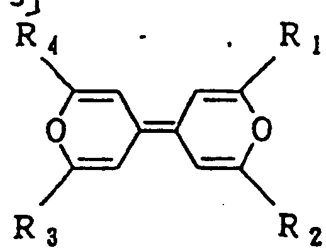




etc.

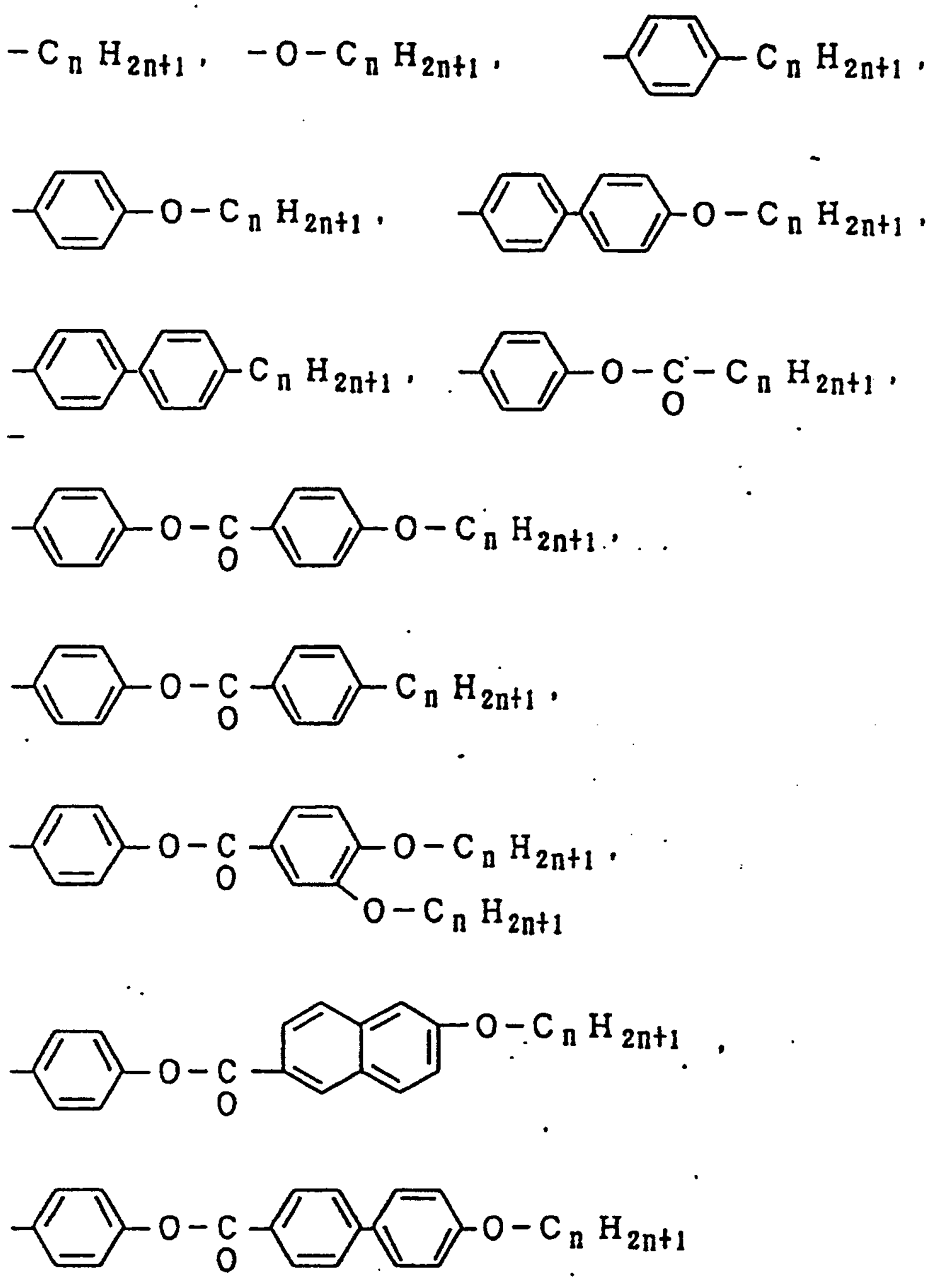
wherein n is an integer of 1-18, preferably 3-14, and m is an integer of 2-16, preferably 4-12.

[Structural formula 3]



wherein R_1, R_2, R_3 and R_4 are each a monofunctional or bifunctional substituent group selected from the following groups:

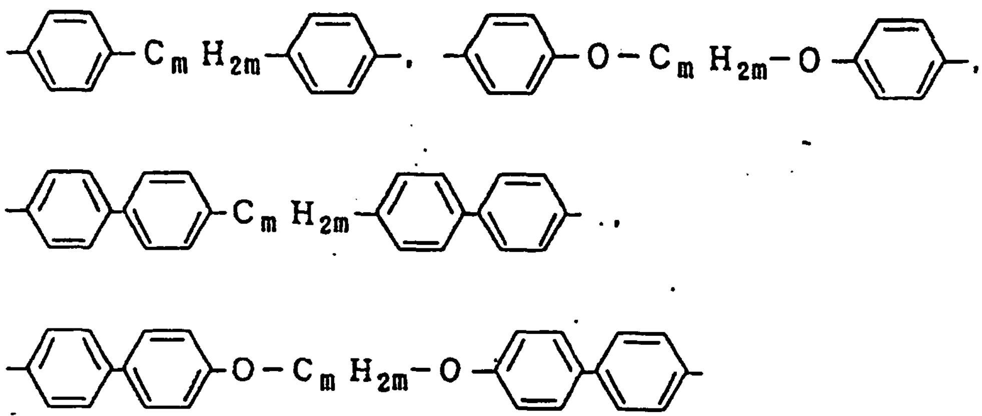
Monofunctional substituent groups:



etc.

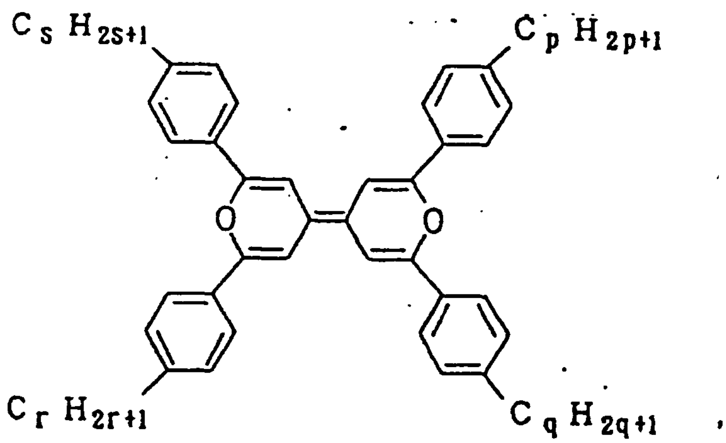
wherein n is an integer of 1-18, preferably 3-14, and m is an integer of 2-16, preferably 4-12.

Bifunctional substituent groups:

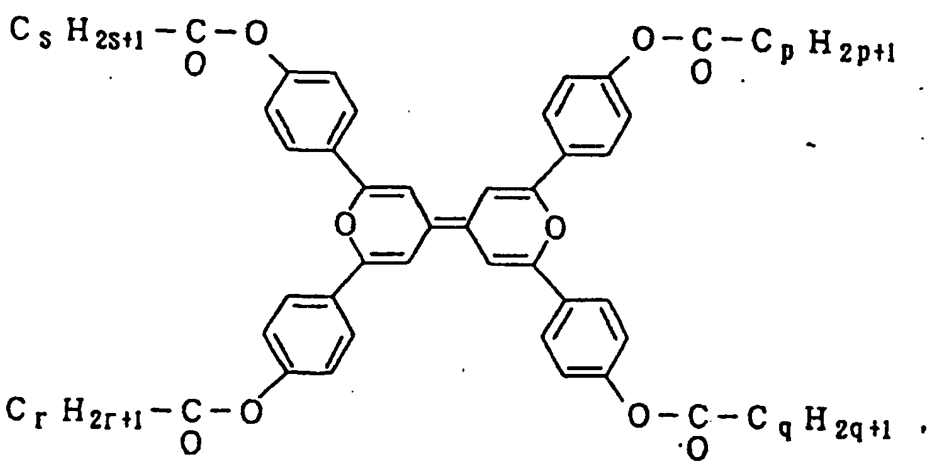


etc.

wherein C_mH_{2m} is a linear or branched alkylene chain, and m is an integer of 2-16, preferably 4-12. Examples of the concrete structures:

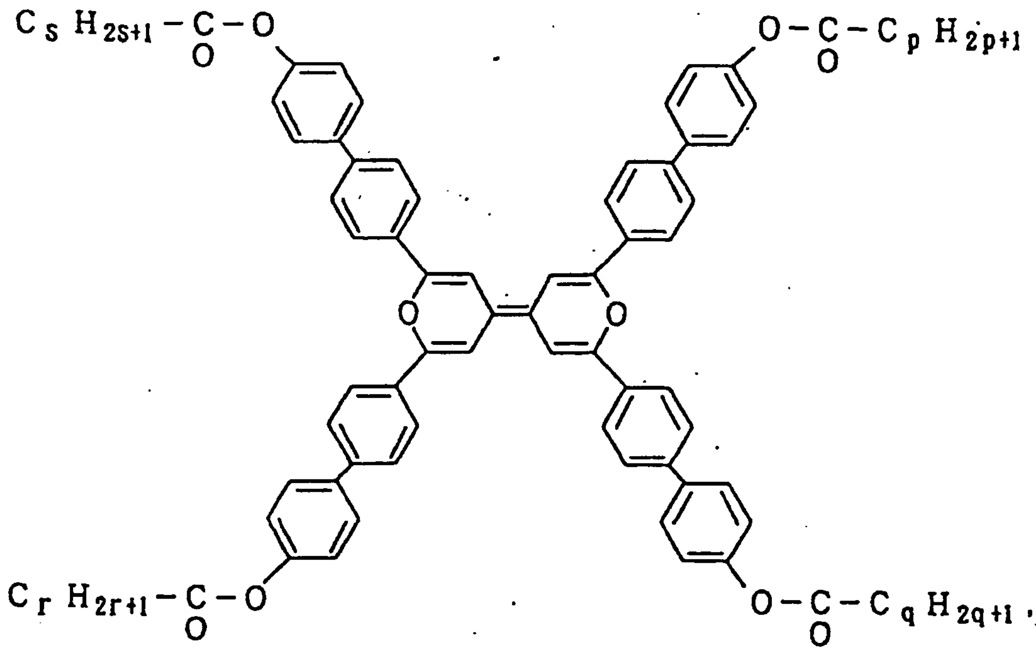


wherein p, q, r and s are each an integer of 1-18, preferably 3-14.

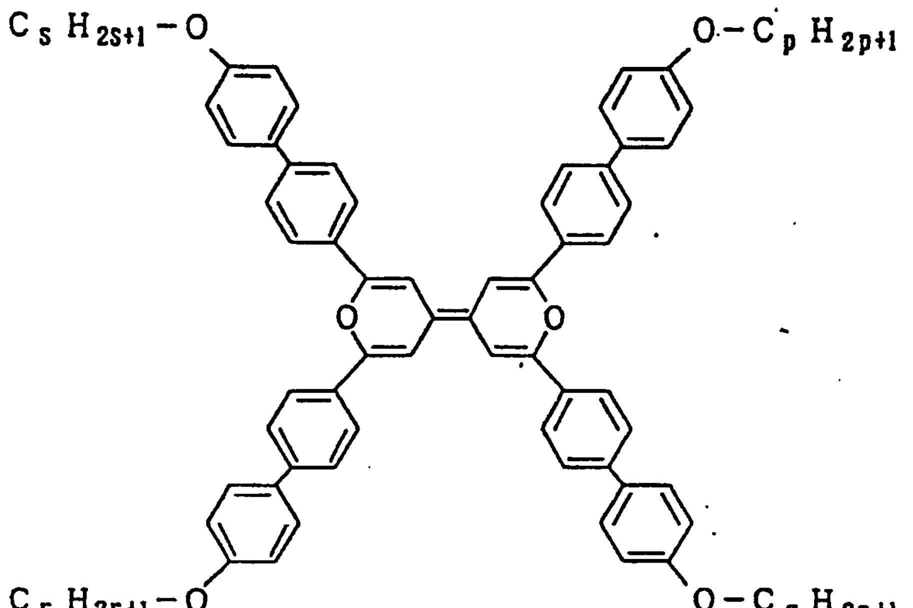


wherein p, q, r and s are each an integer of 1-18, preferably 3-14.

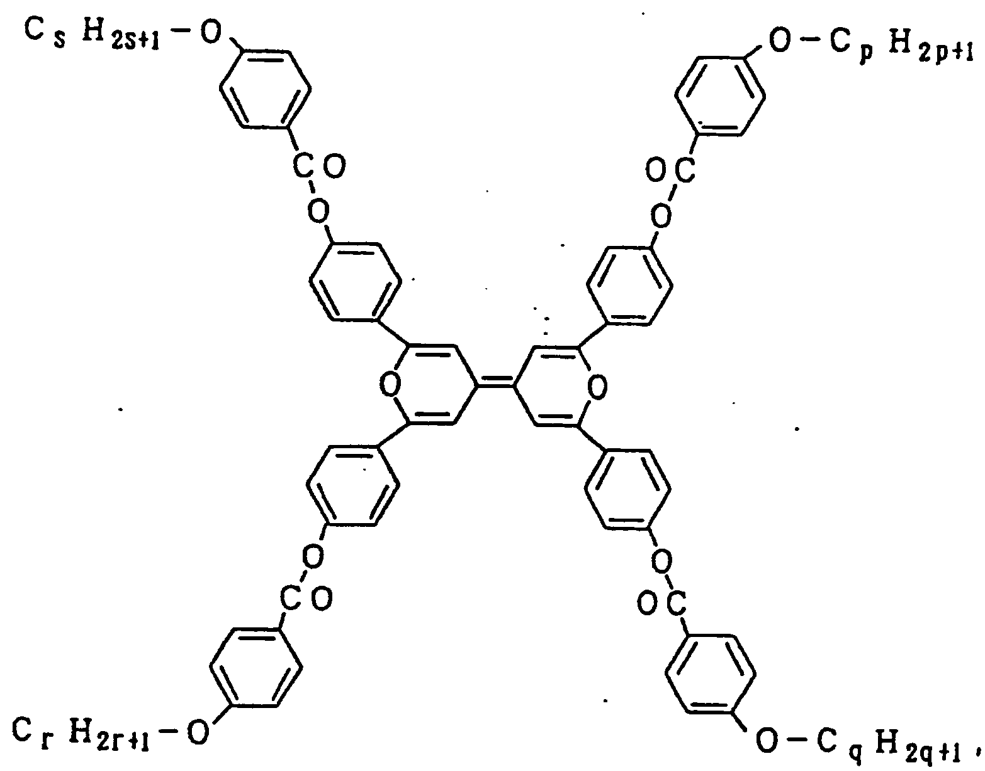
2



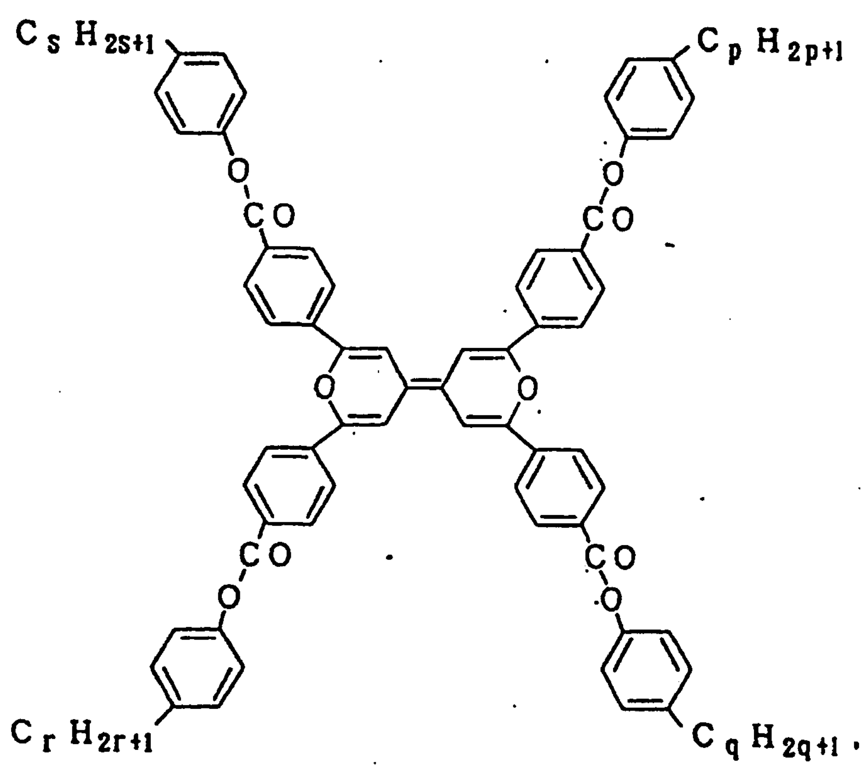
wherein p, q, r and s are each an integer of 1-18, preferably 3-14.



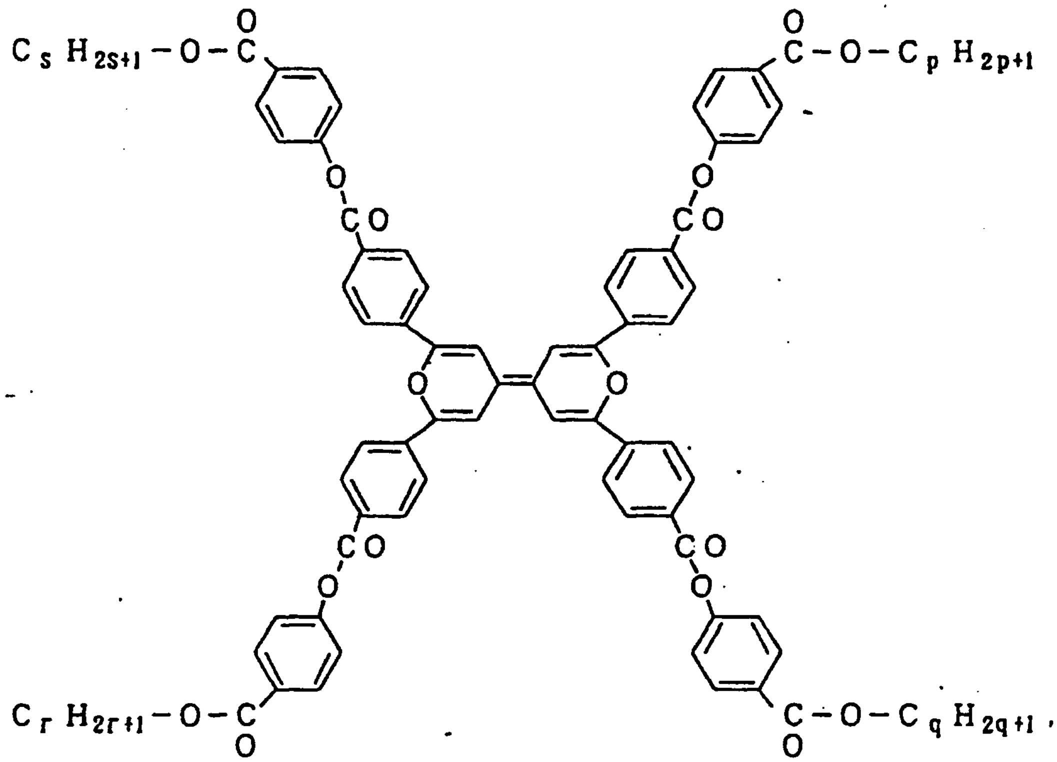
wherein p, q, r and s are each an integer of 1-18, preferably 3-14.



wherein p, q, r and s are each an integer of 1-18, preferably 3-14.

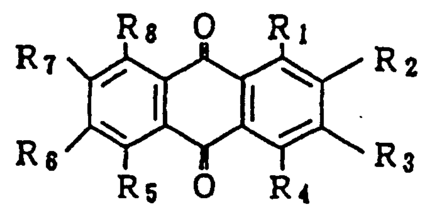


wherein p, q, r and s are each an integer of 1-18, preferably 3-14.



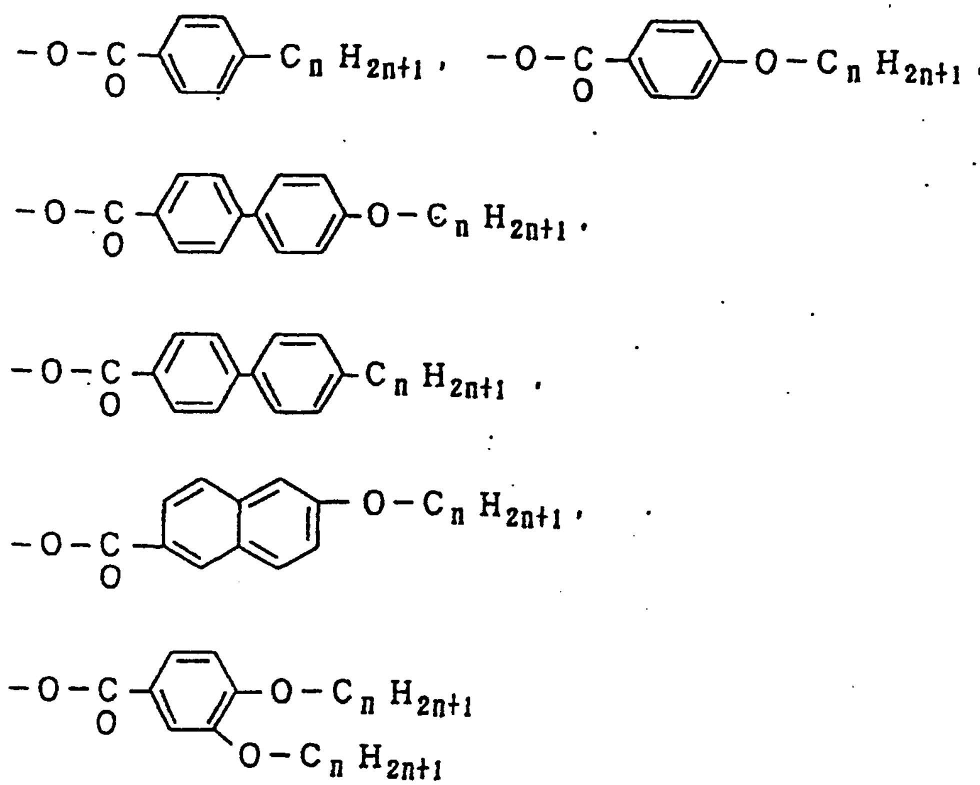
wherein p, q, r and s are each an integer of 1-18, preferably 3-14.

[Structural formula 4]



wherein R_1-R_8 are each independently a monofunctional or bifunctional substituent group selected from the following groups:
Monofunctional substituent groups:
-H (at most 4),

$-C_nH_{2n+1}$, $-O-C_nH_{2n+1}$, $-O-\underset{O}{C}-C_nH_{2n+1}$,

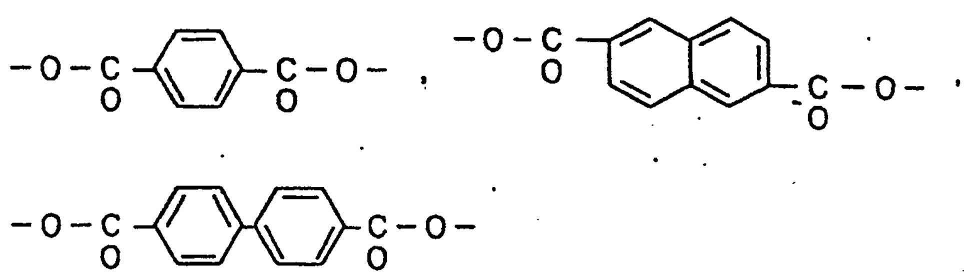


etc.

wherein C_nH_{2n+1} is a linear or branched alkyl group, and n is an integer of 1-18, preferably 3-14.

Bifunctional substituent groups:

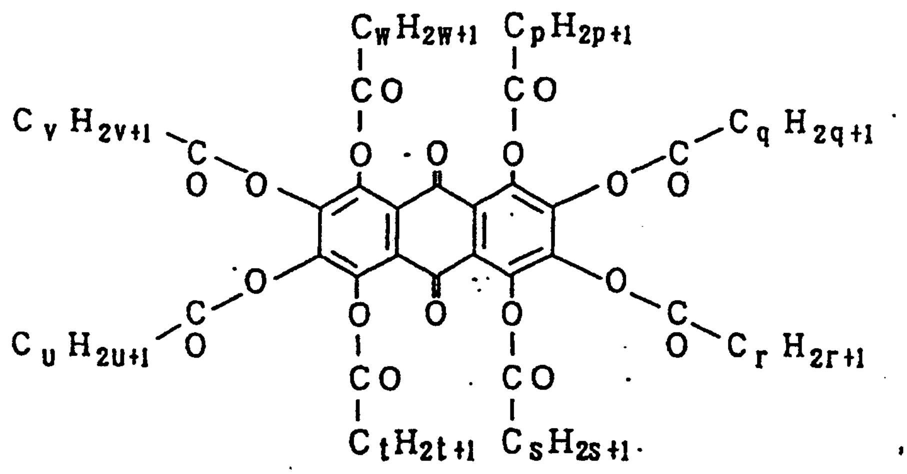
$-O-\underset{O}{C}-C_mH_{2m}-\underset{O}{C}-O-$, $-O-C_mH_{2m}-O-$,



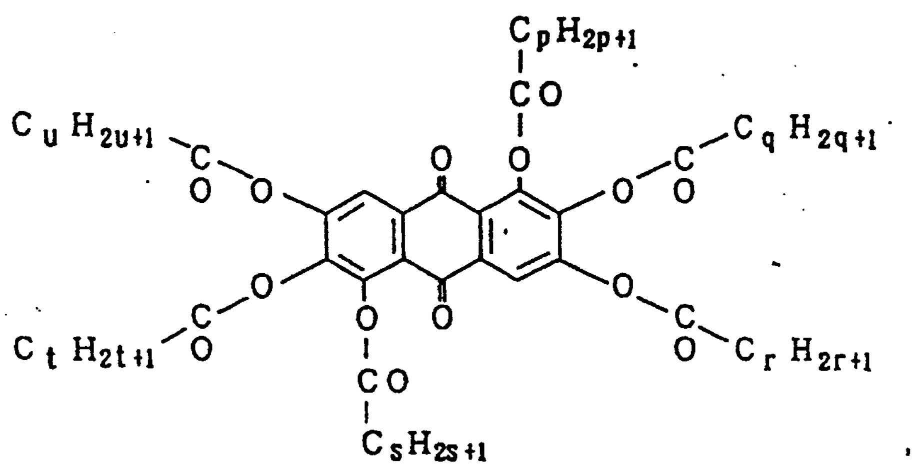
etc.

wherein C_mH_{2m} is a linear or branched alkylene chain, and m is an integer of 2-16, preferably 4-12.

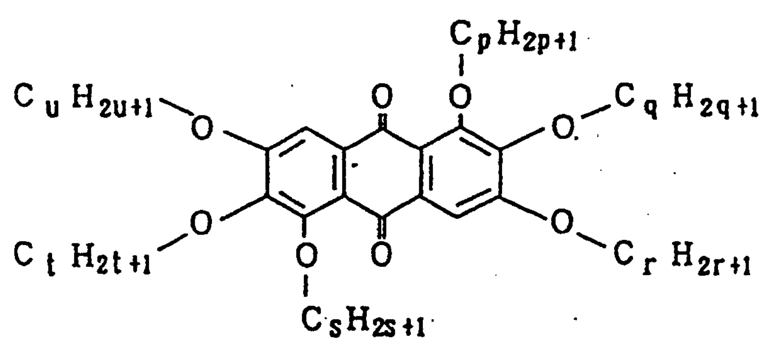
Examples of the concrete structures:



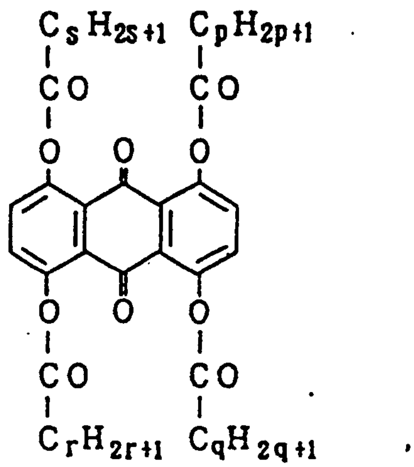
wherein p, q, r, s, t, u, v and w are each an integer of 1-18, preferably 3-14.



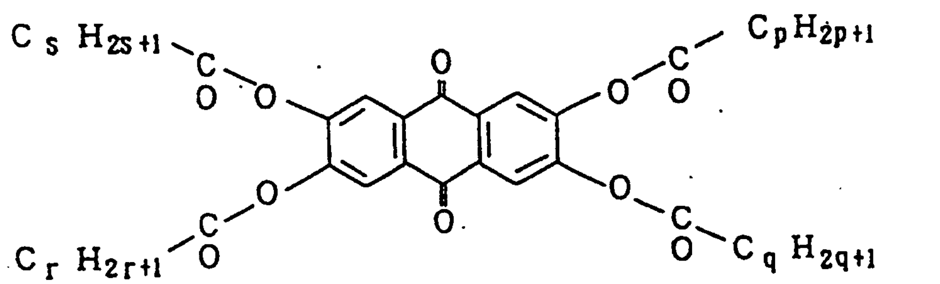
wherein p, q, r, s, t, and u are each an integer of 1-18, preferably 3-14.



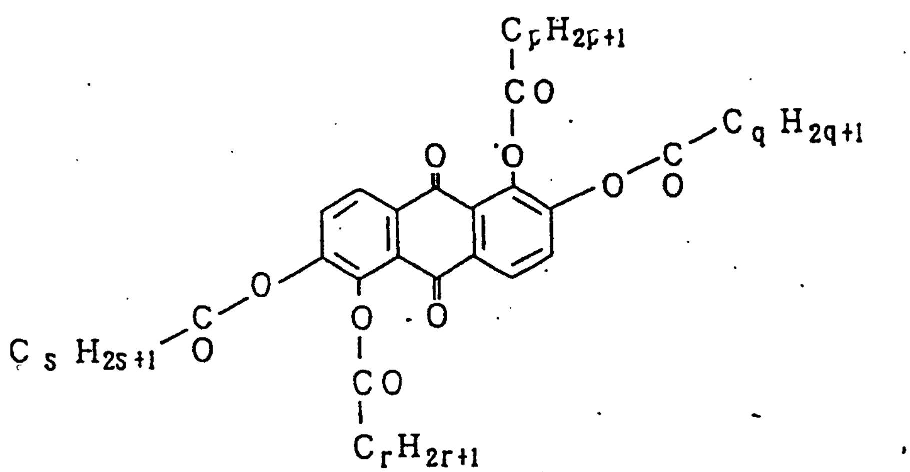
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



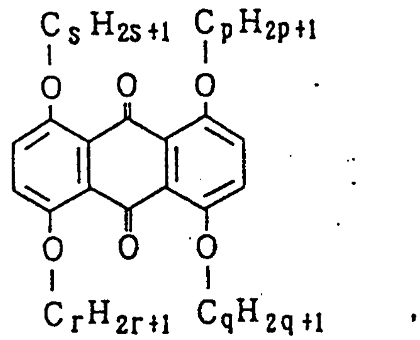
wherein p, q, r, and s are each an integer of 1-18, preferably 3-14.



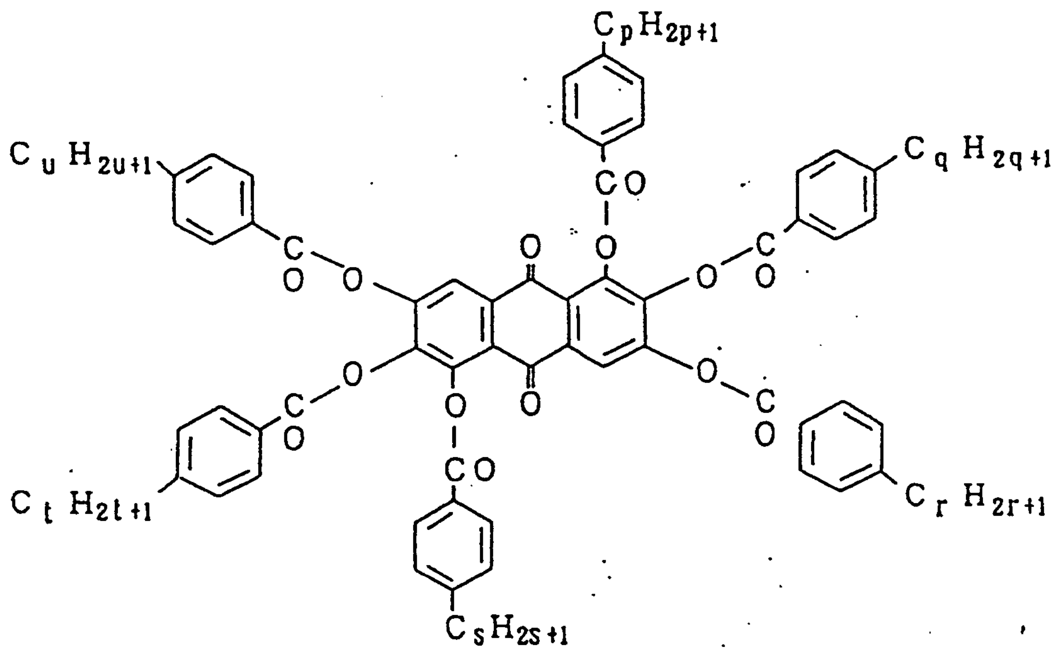
wherein p, q, r, and s are each an integer of 1-18, preferably 3-14.



wherein p, q, r, and s are each an integer of 1-18, preferably 3-14.

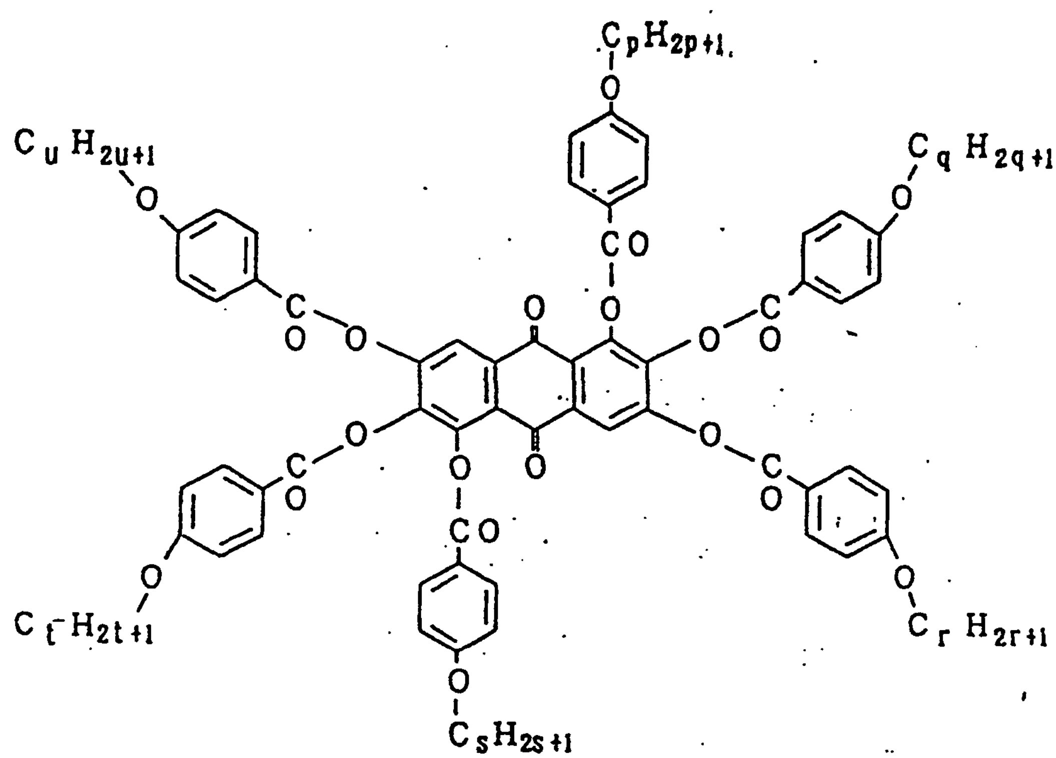


wherein p, q, r, and s are each an integer of 1-18, preferably 3-14.

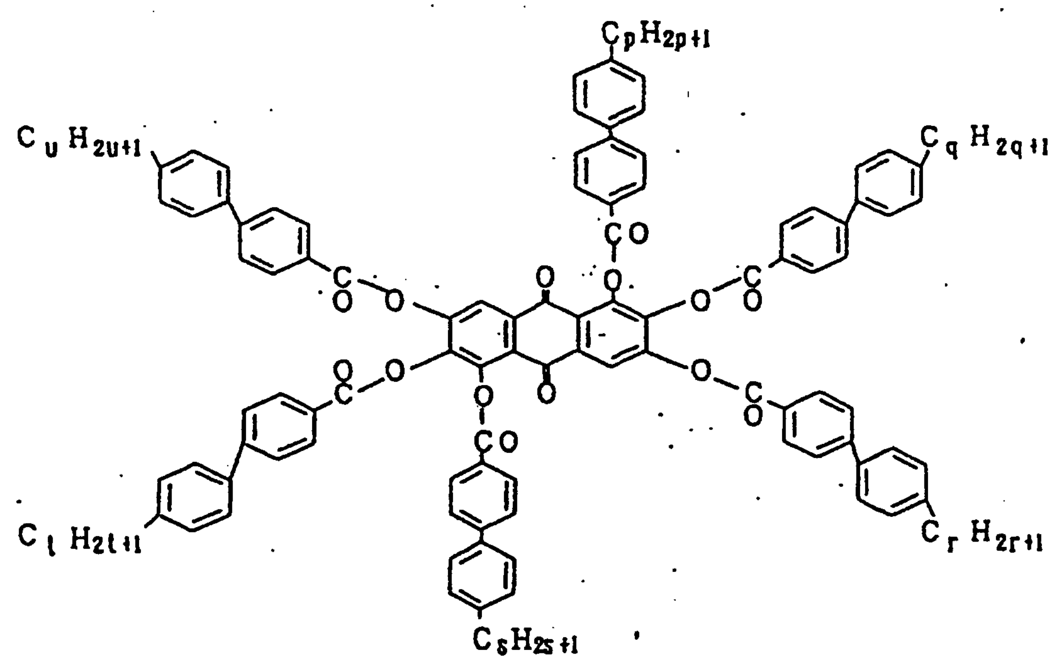


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

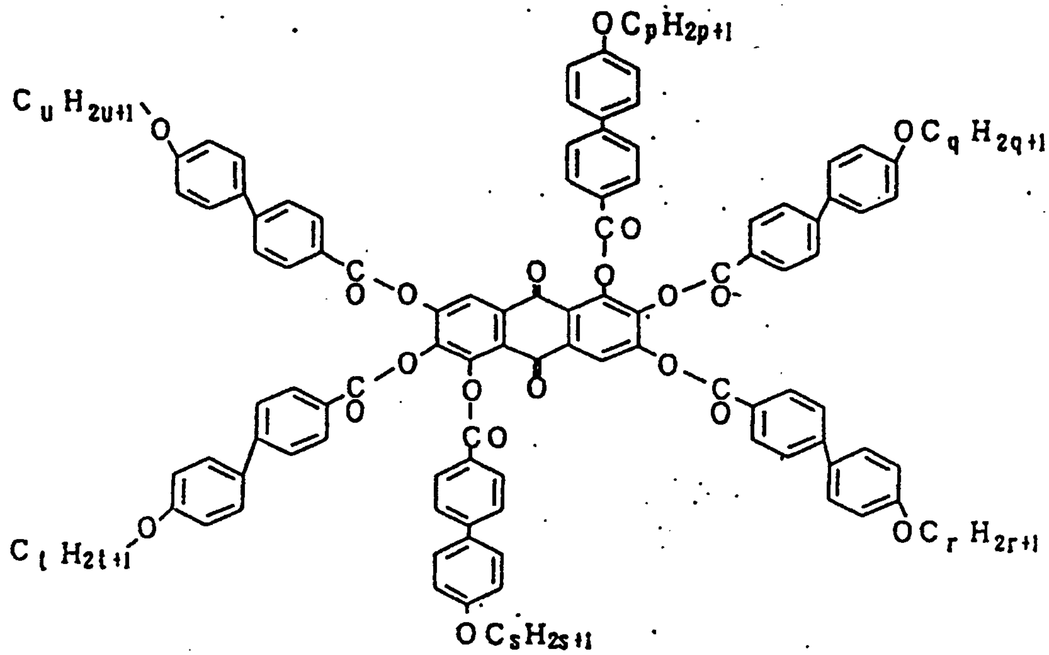
3



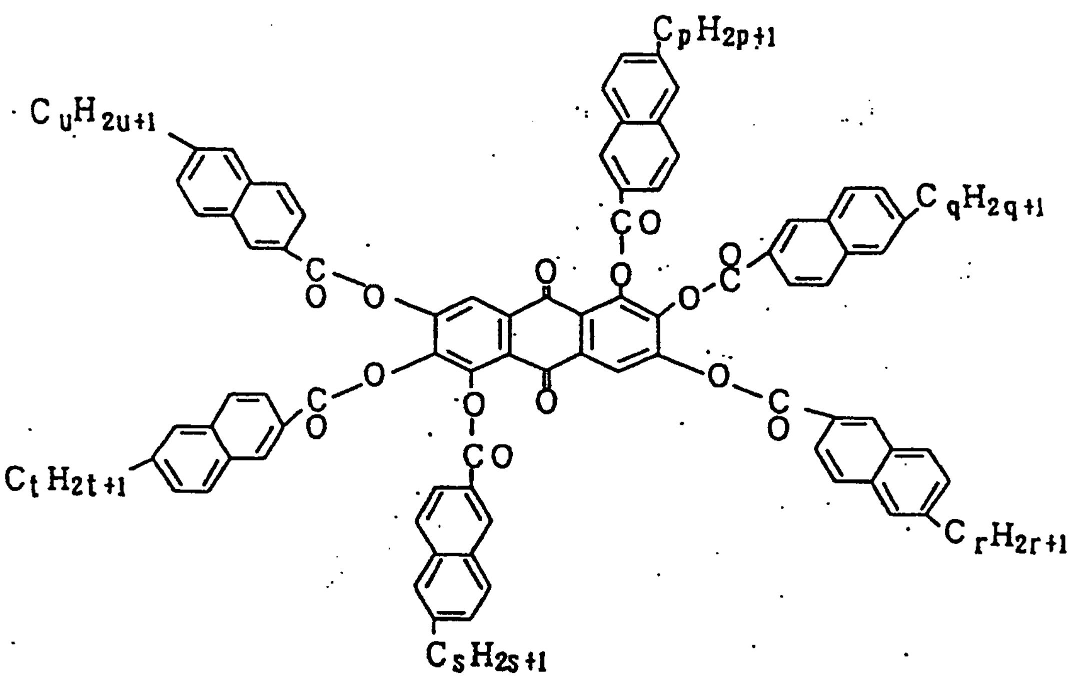
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



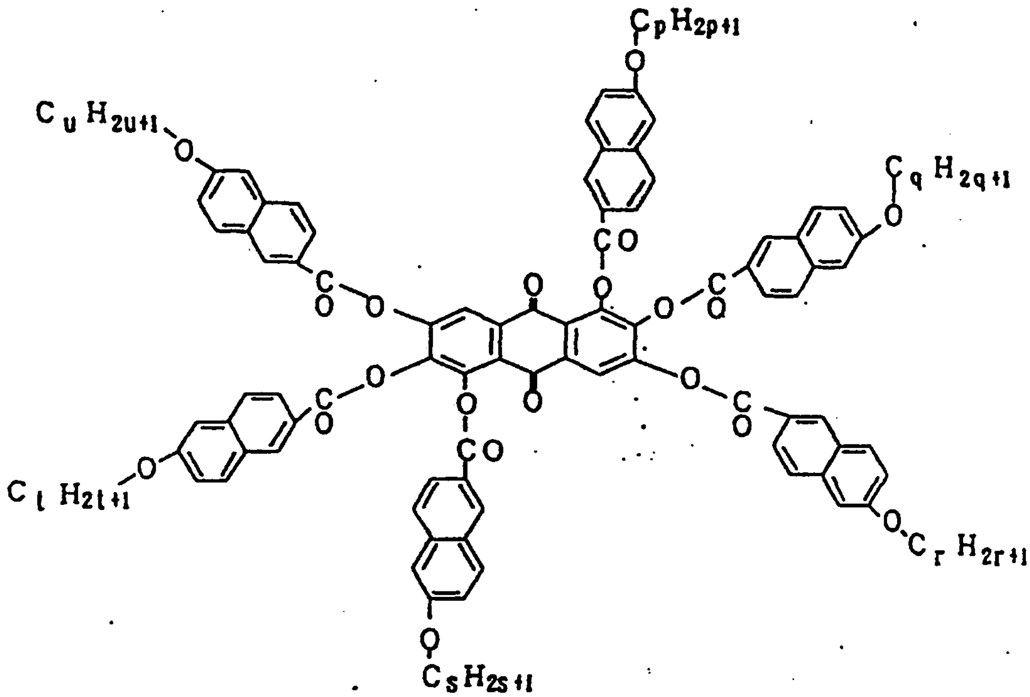
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

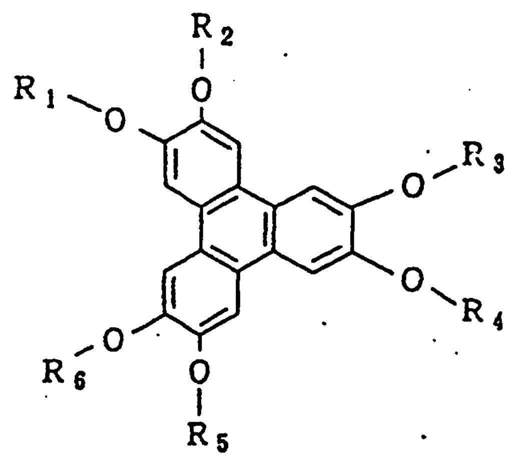


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

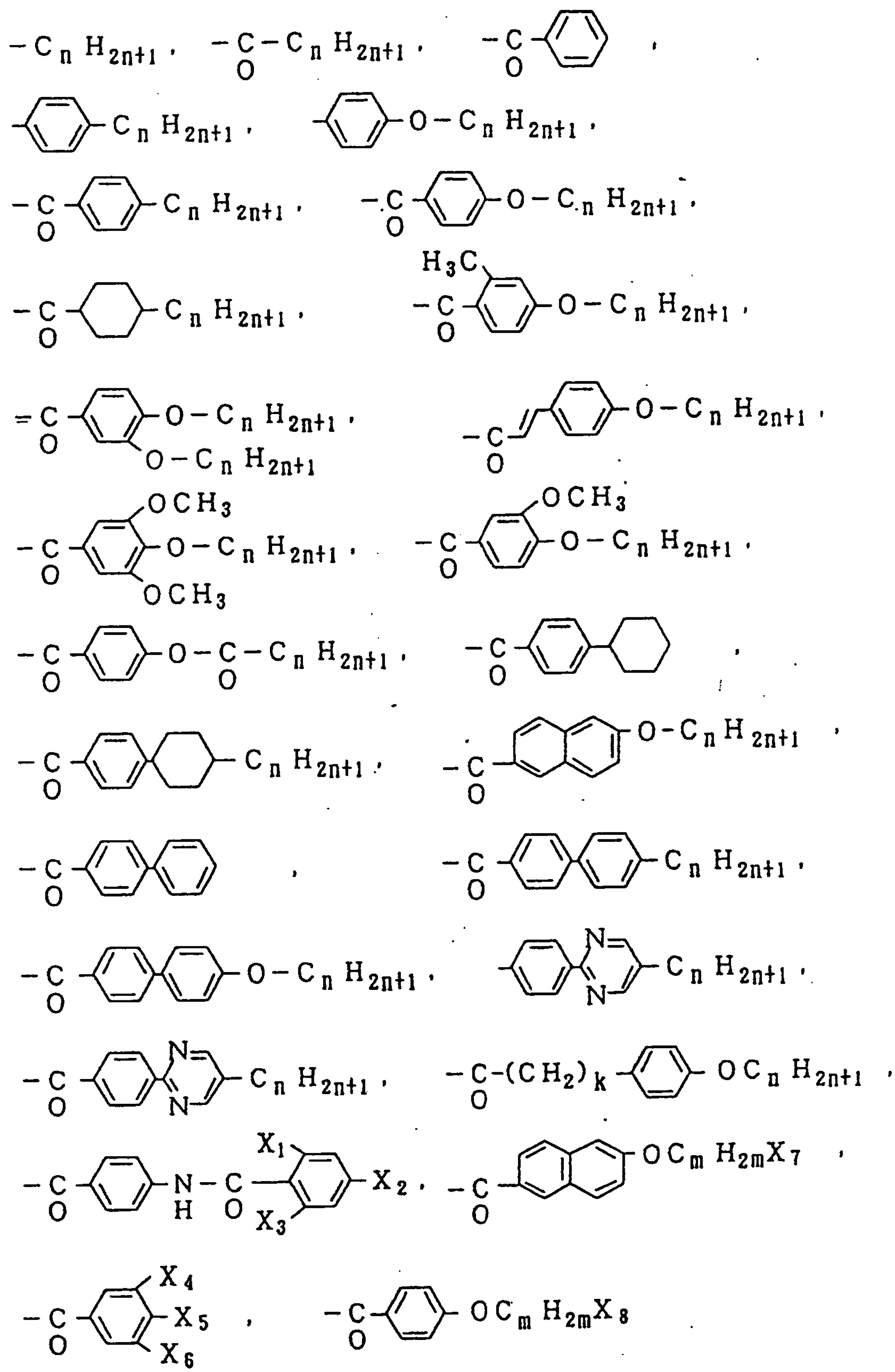


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

[Structural formula 5]



wherein R_1-R_6 are each a monofunctional or bifunctional substituent group selected from the following groups: Monofunctional substituent groups:

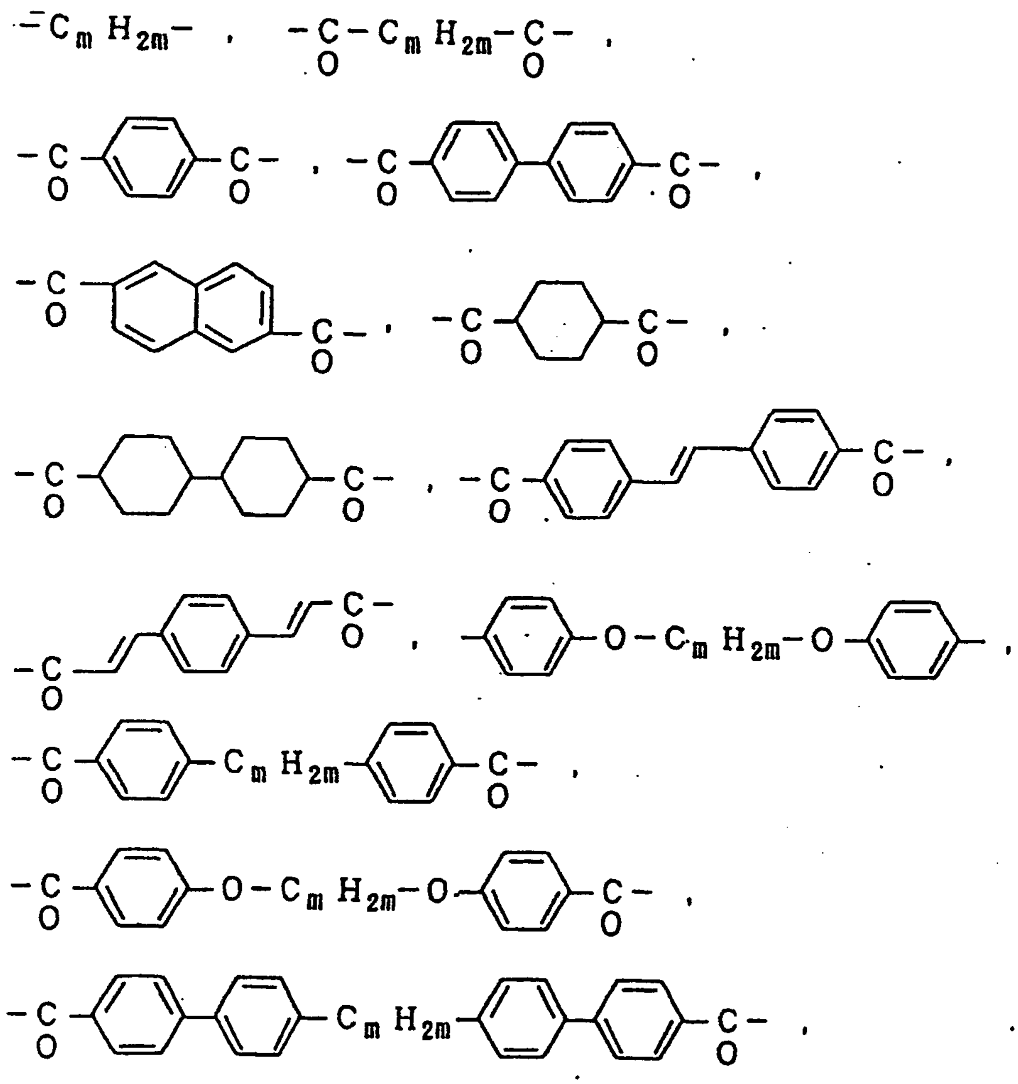


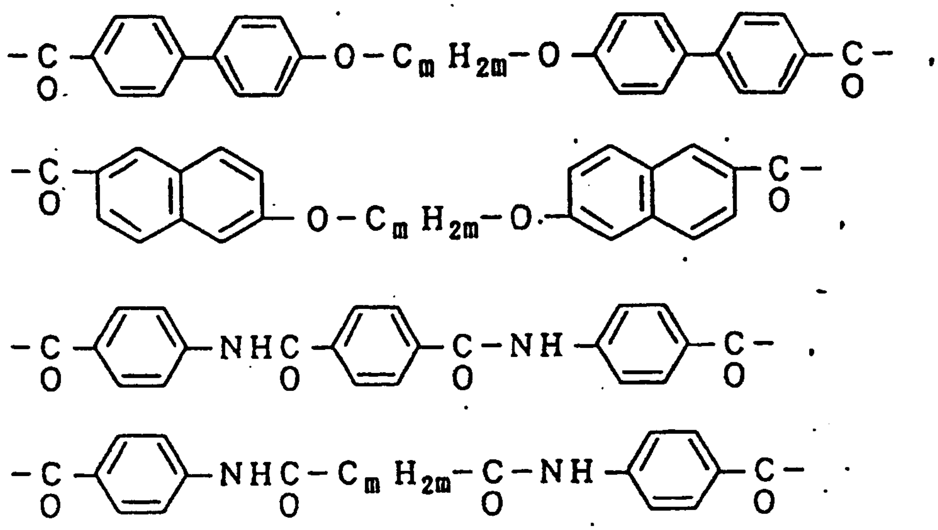
etc.

wherein C_nH_{2n+1} is a linear or branched alkyl group, n is an integer of 1-18, preferably 3-14, X_1-X_8 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10, C_mH_{2m} is a linear or branched alkylene group, and m is an integer

of 1-16, preferably 2-10.

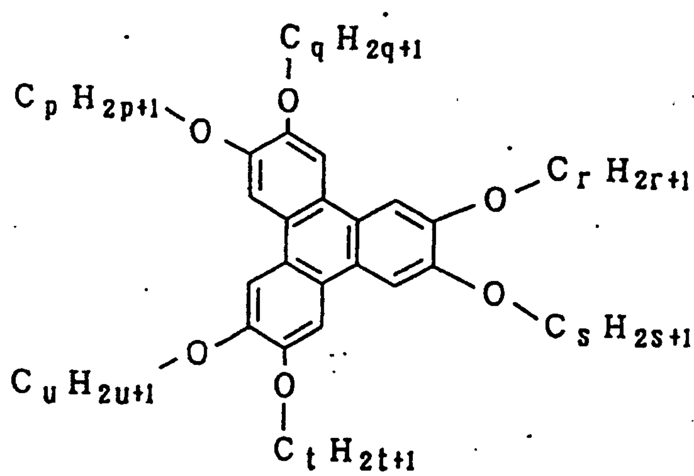
Bifunctional substituent groups:



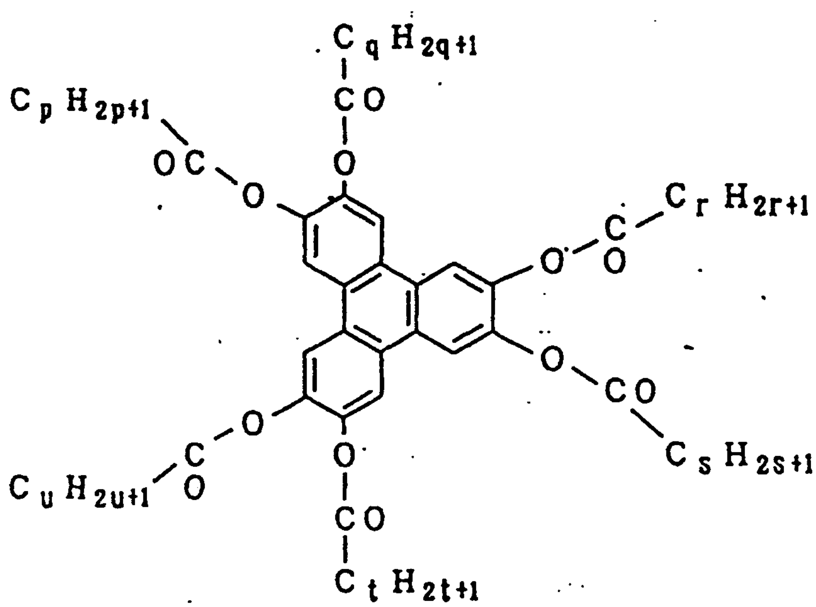


etc.

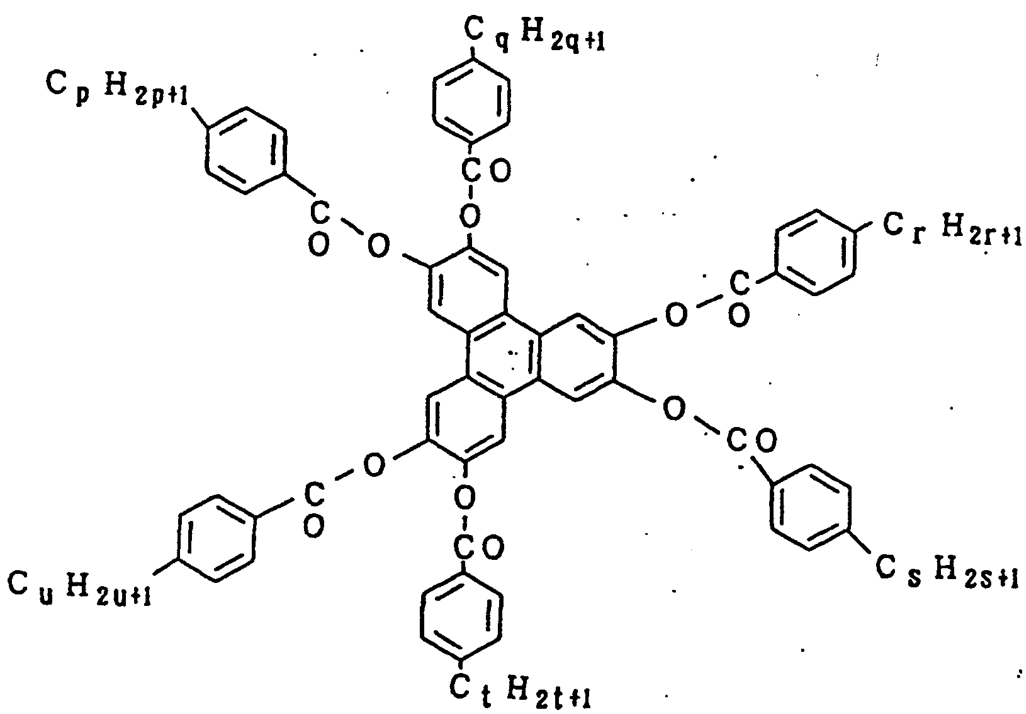
wherein C_mH_{2m} is a linear or branched alkylene group, and m is an integer of 2-16, preferably 4-12. Examples of the concrete structures:



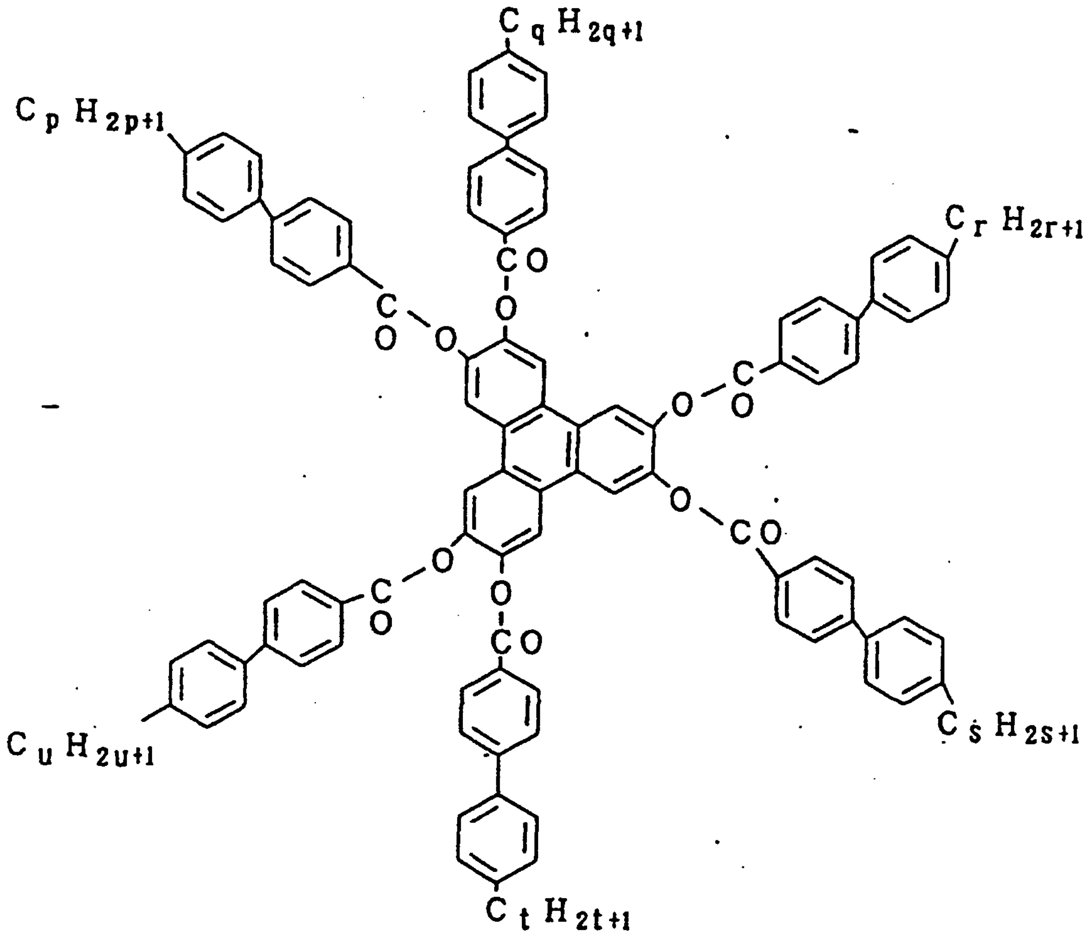
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



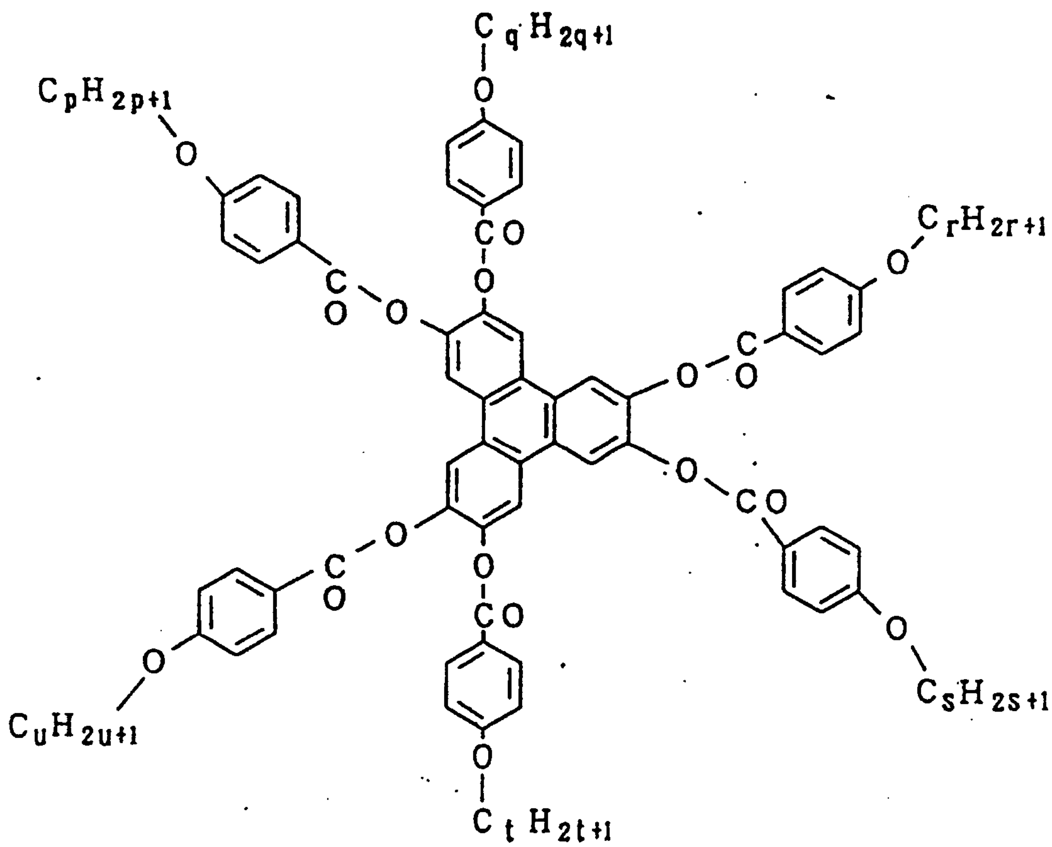
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



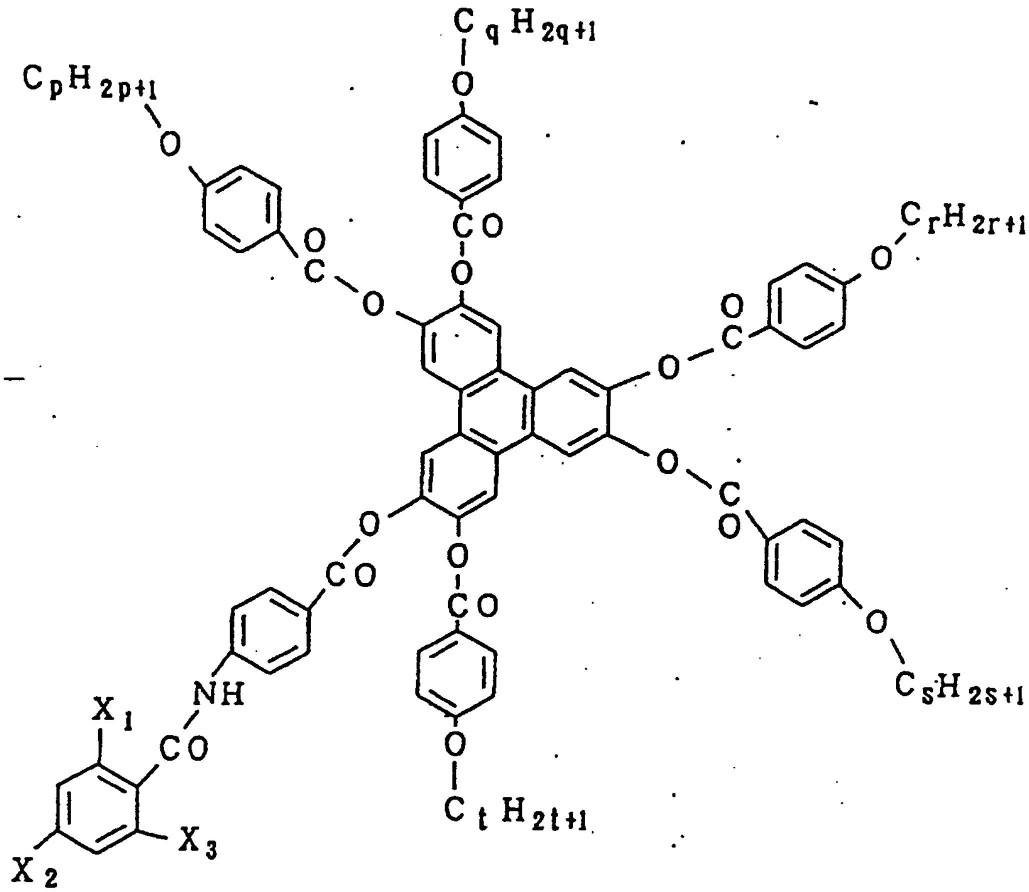
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



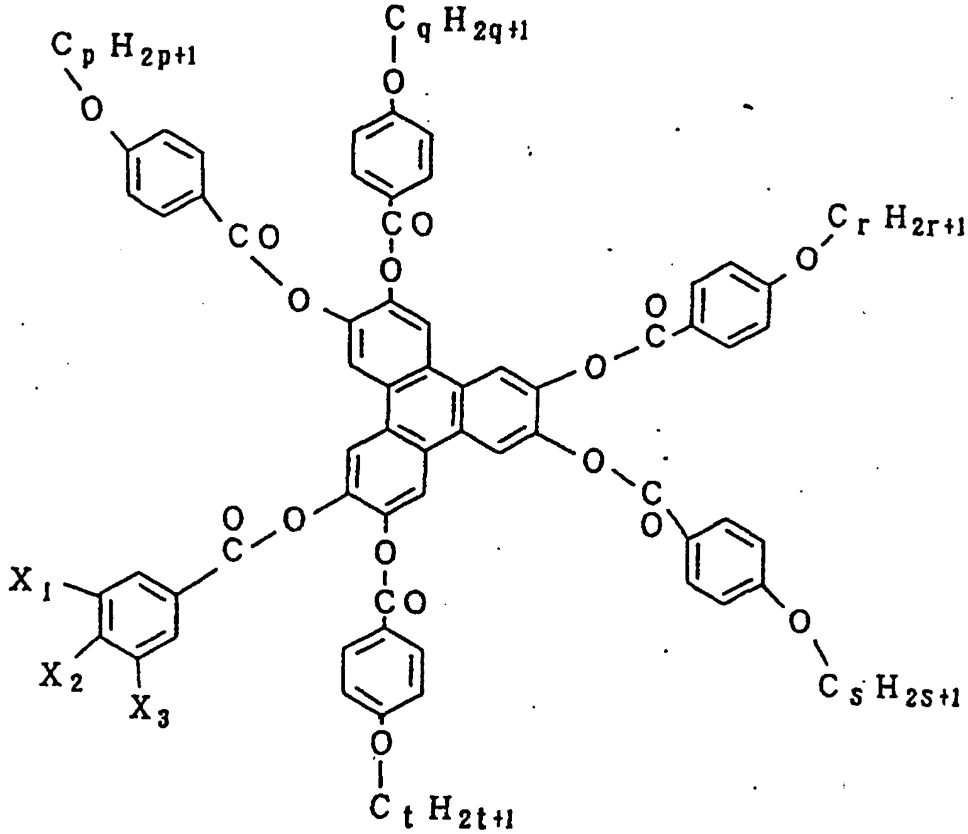
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



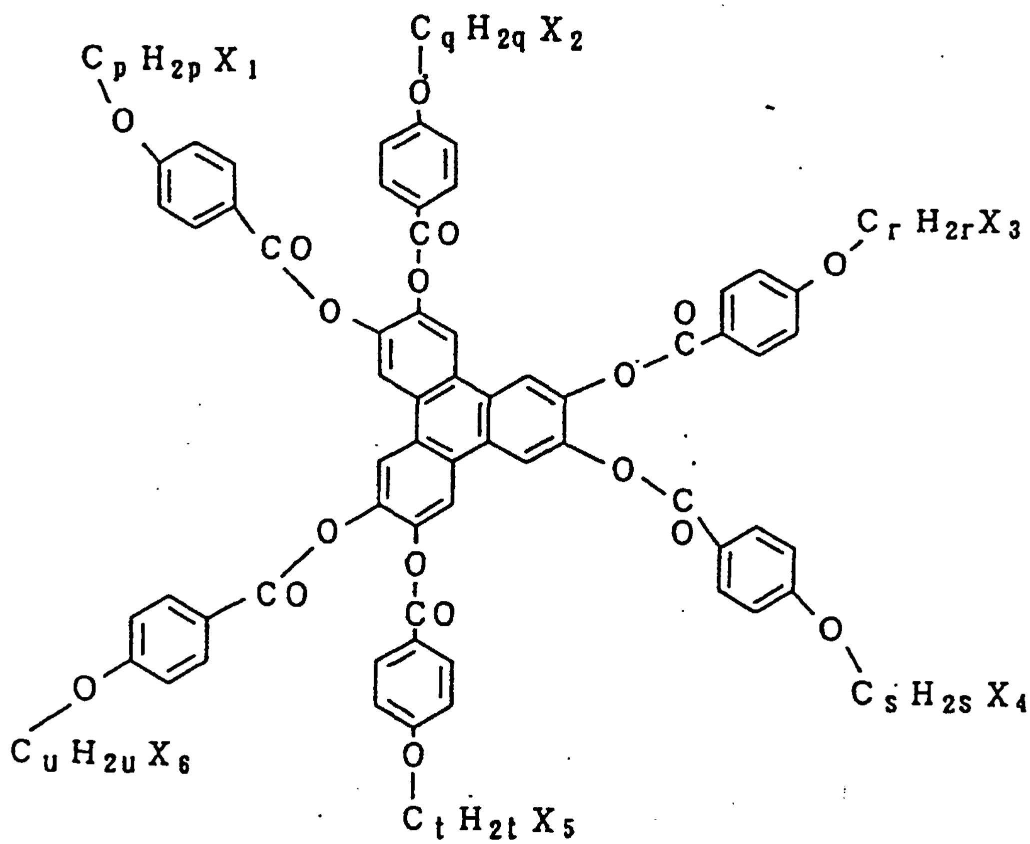
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



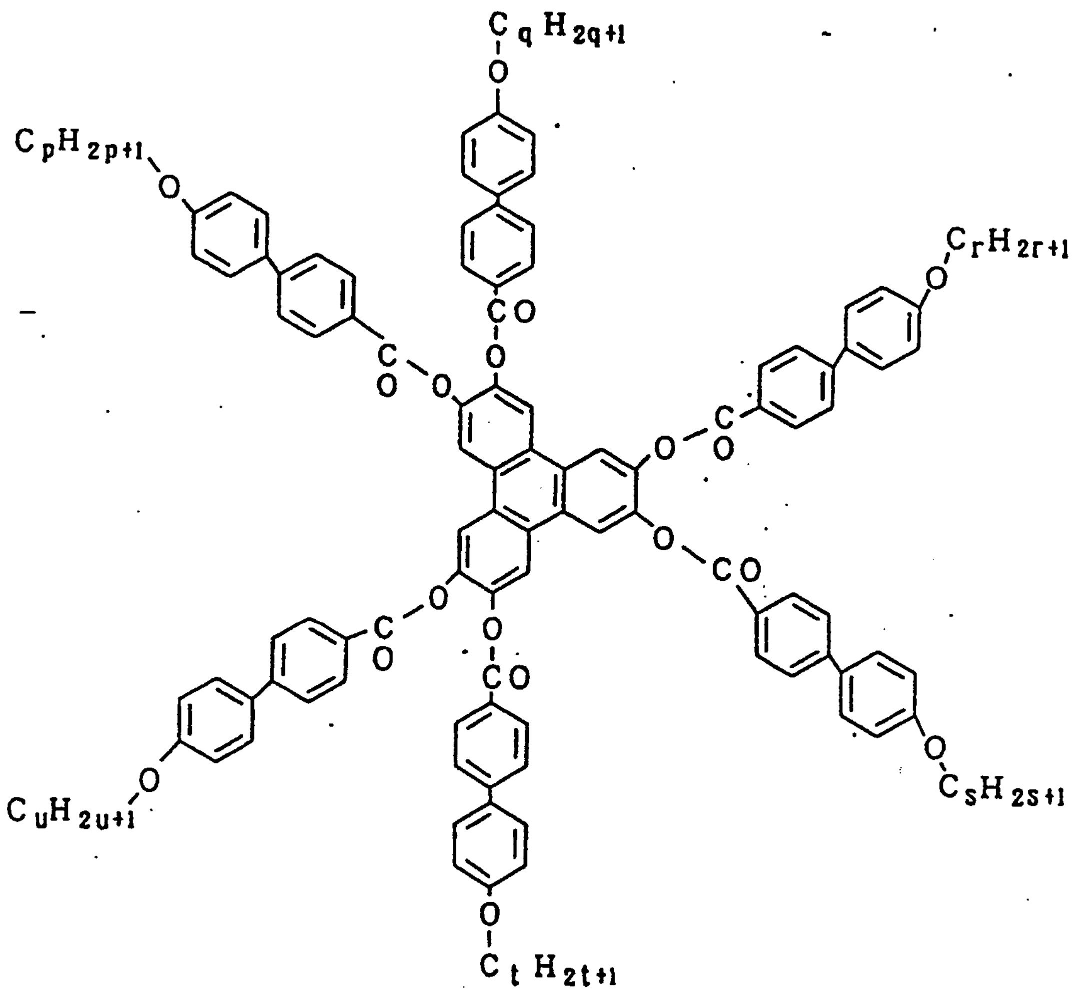
wherein p, q, r, s and t are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



wherein p, q, r, s and t are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10

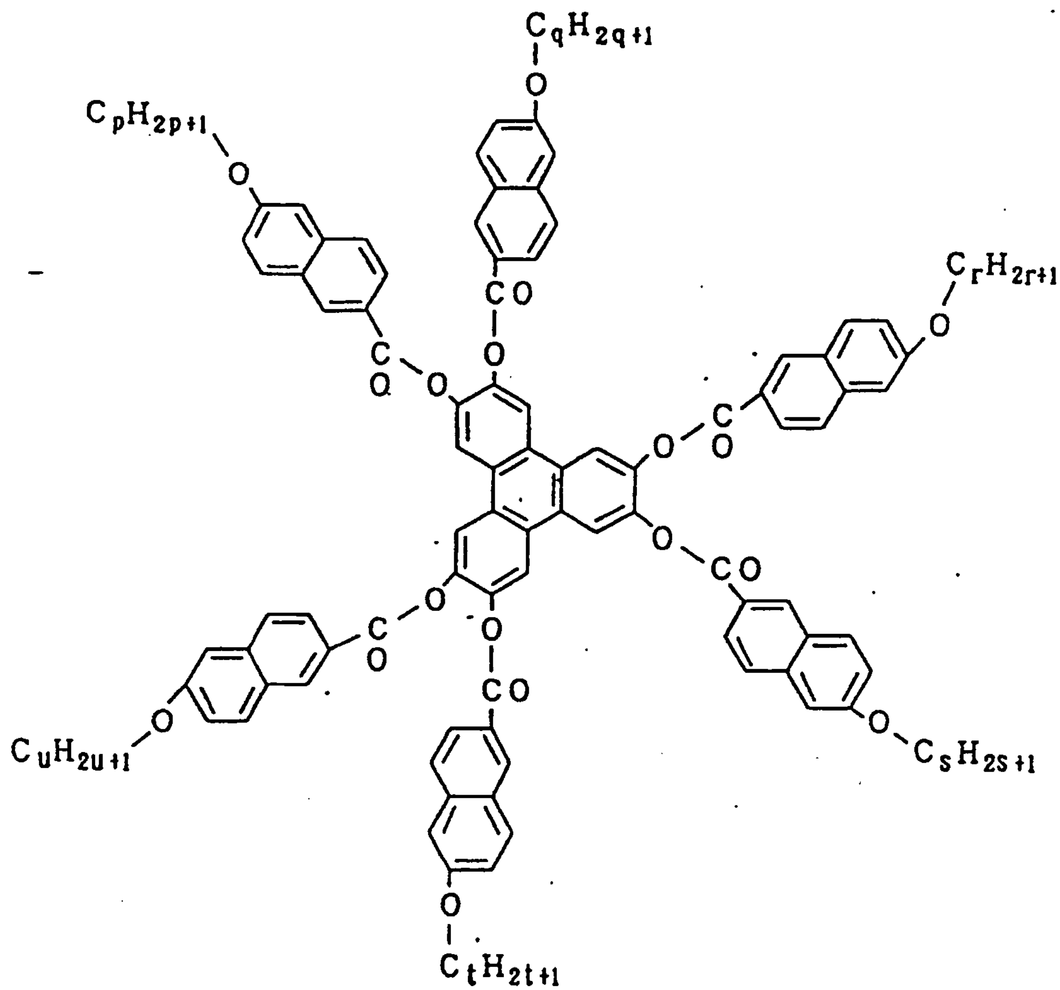


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14, X_1-X_6 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

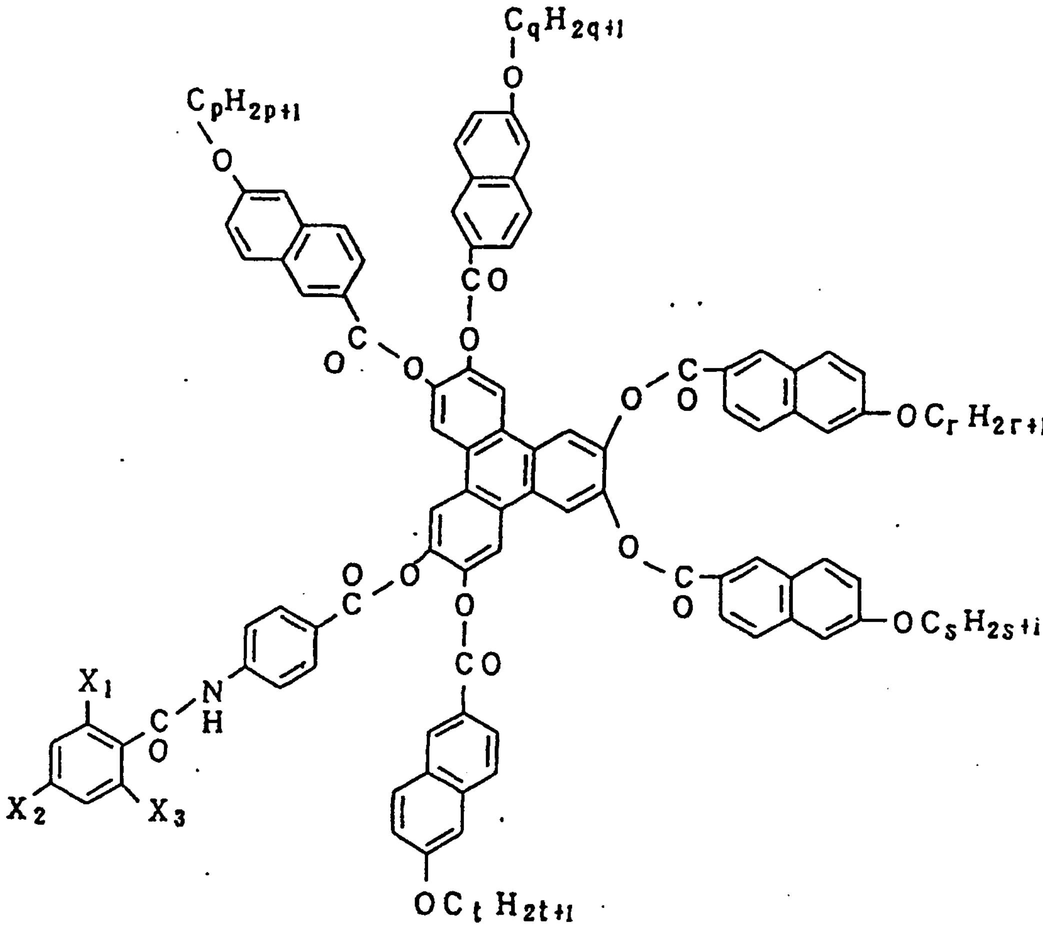


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

4

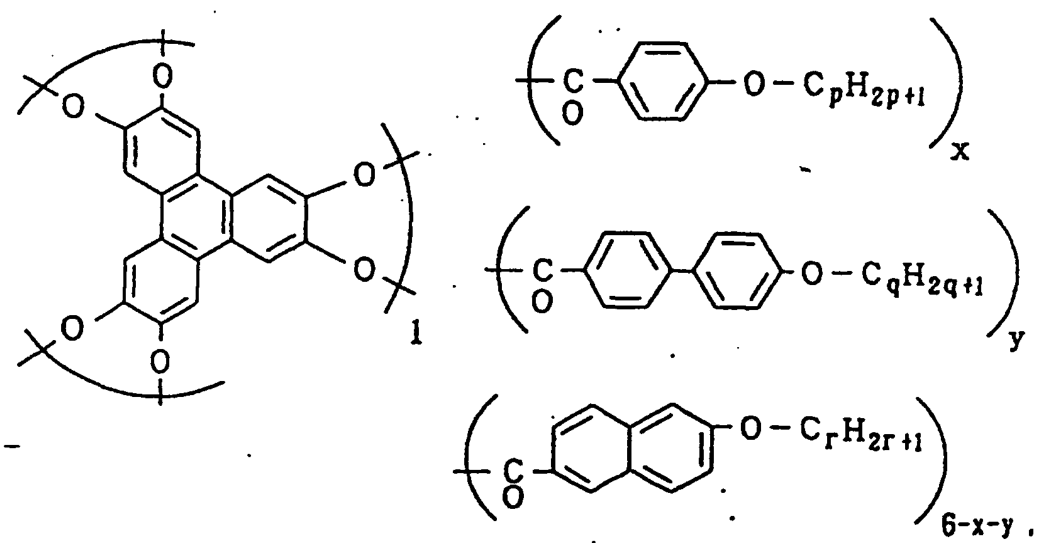


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



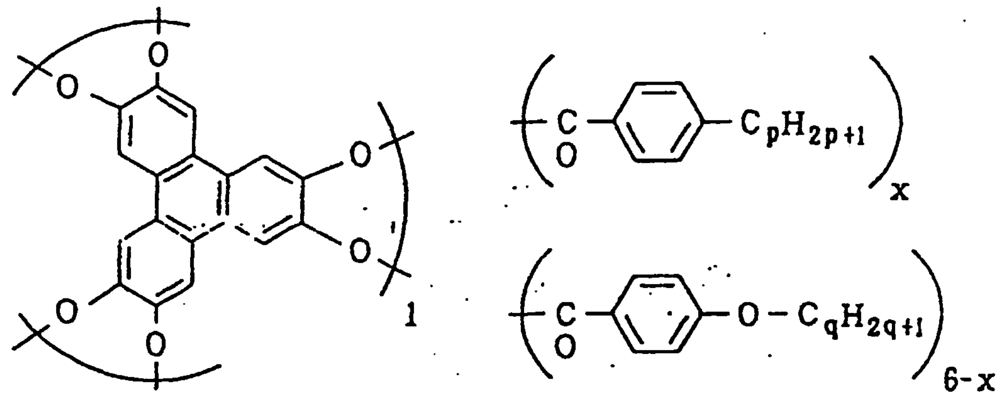
wherein p, q, r, s and t are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

Composition of the following:



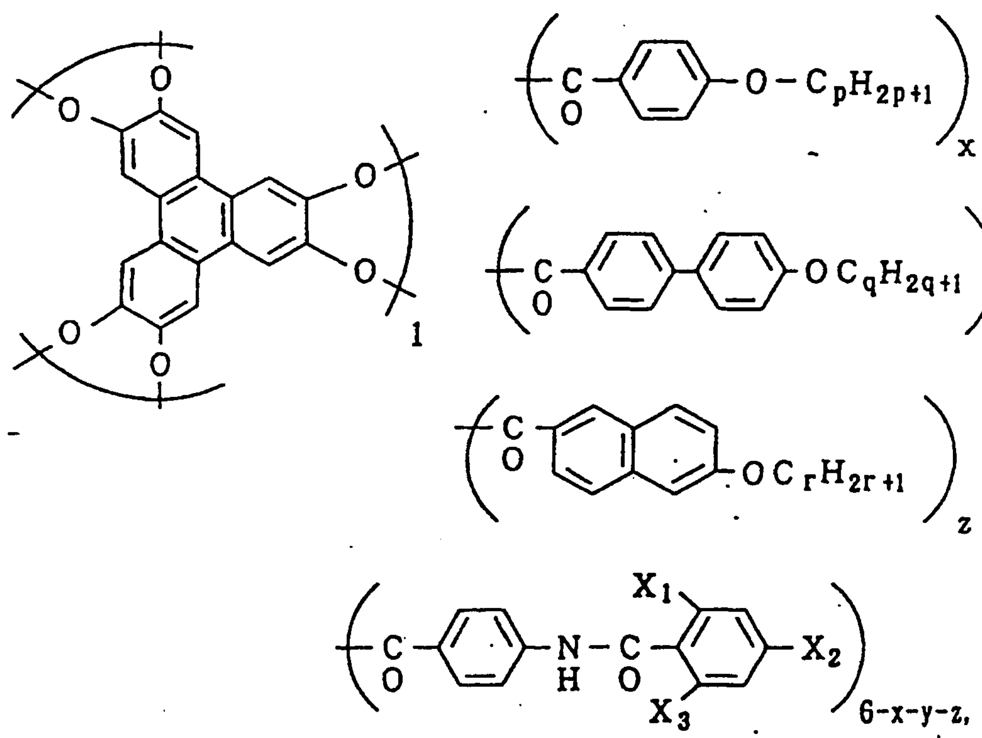
wherein 0≦x≦6, 0≦y≦6 in the molar ratio, and p, q, r are each an integer of 1-18, preferably 3-14.

Composition of the following:



wherein 0≦x≦6 in the molar ratio, and p, q are each an integer of 1-18, preferably 3-14.

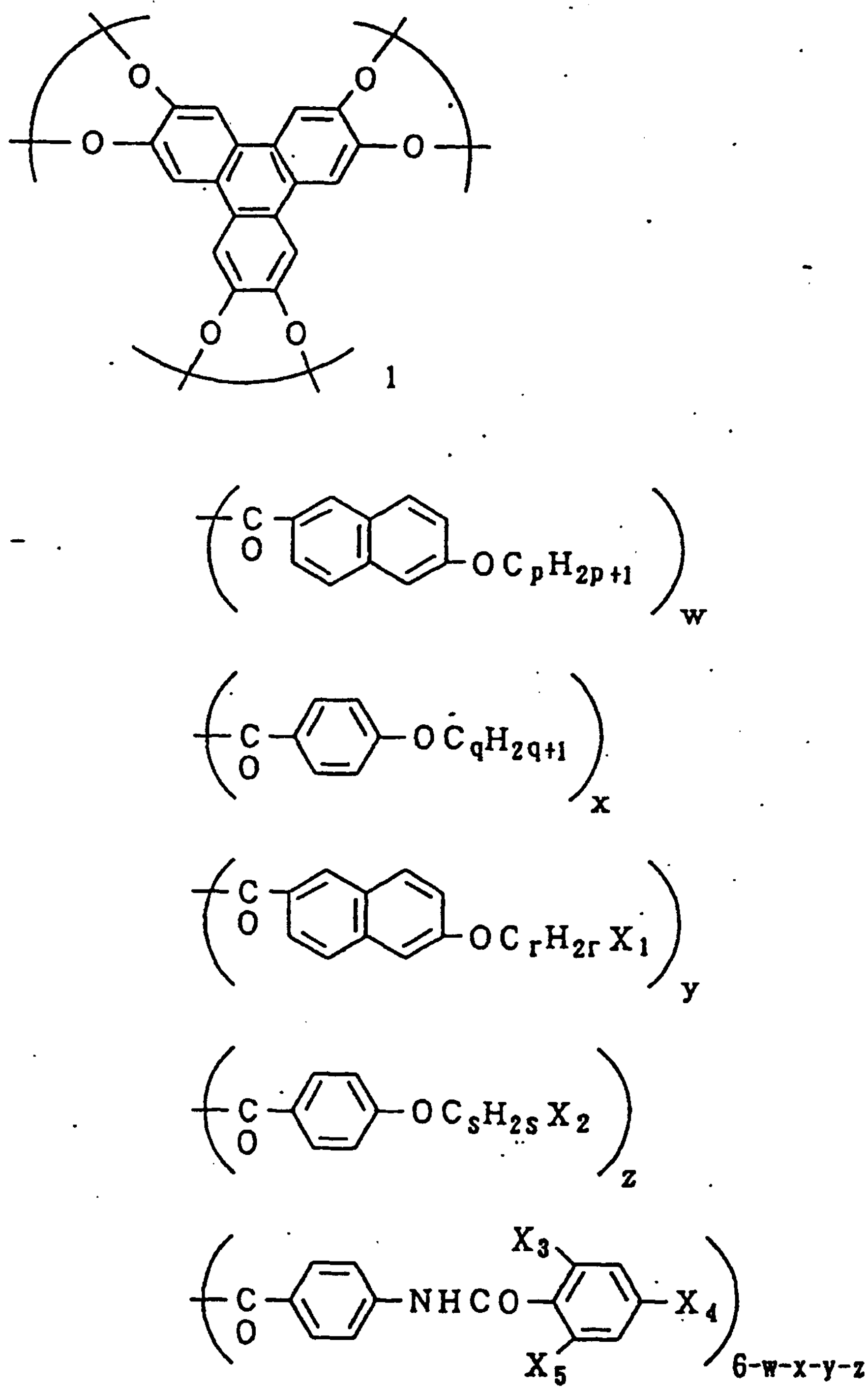
Composition of the following:



wherein 0≦x≦6, 0≦y≦6, 0≦z≦6 in the molar ratio, p, q, and r are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

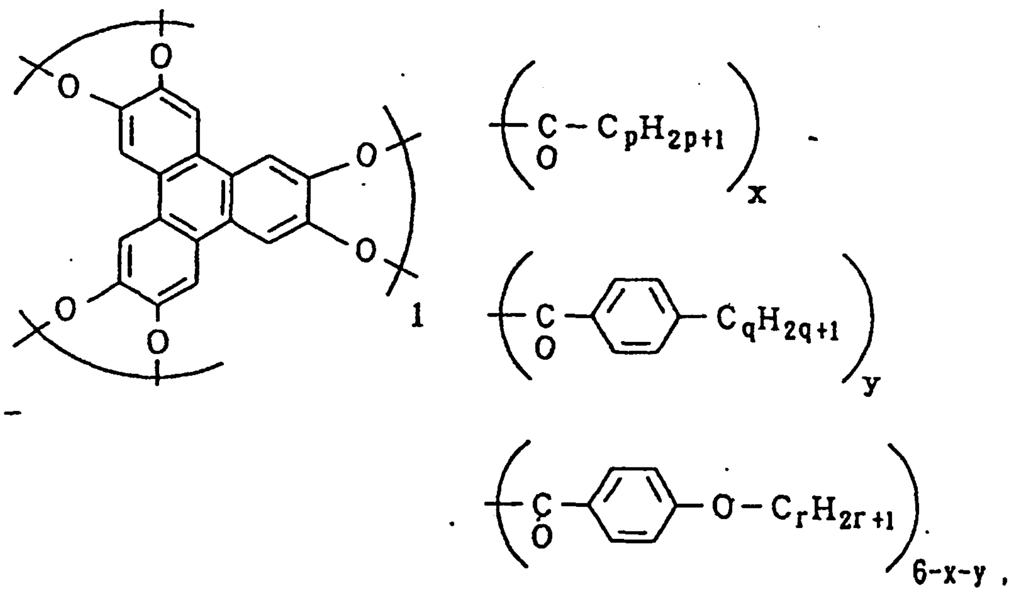
Composition of the following:

4



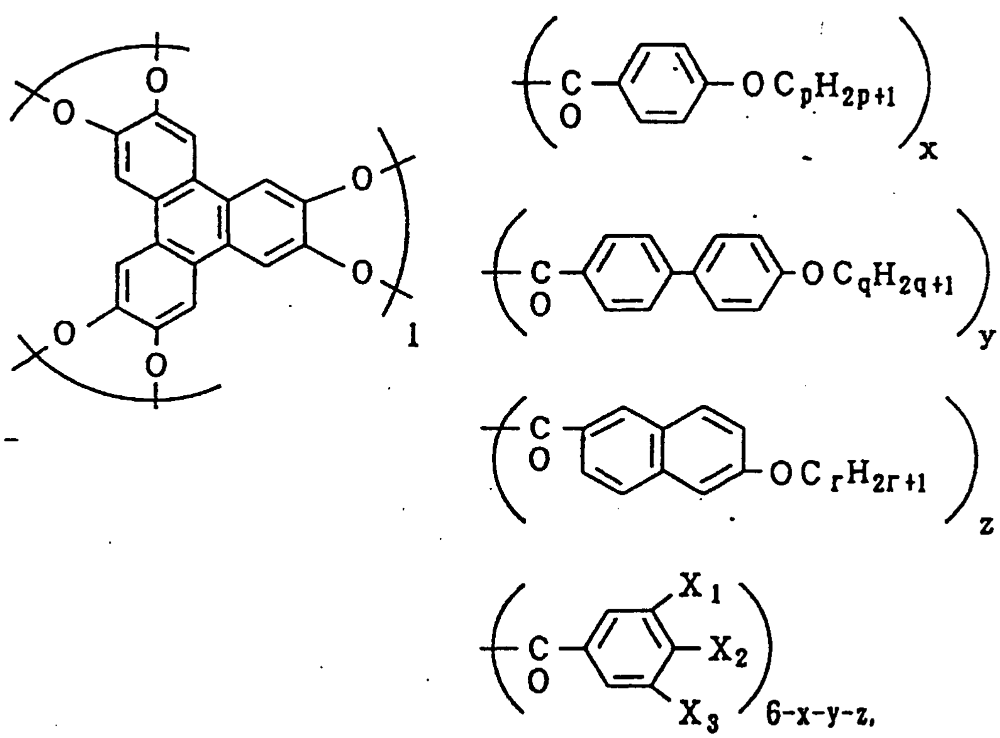
wherein 0≦w≦6, 0≦x≦6, 0≦y≦6, 0≦z≦6 in the molar ratio, p, q, r and s are each an integer of 1-18, preferably 3-14, X_1-X_6 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

Composition of the following:



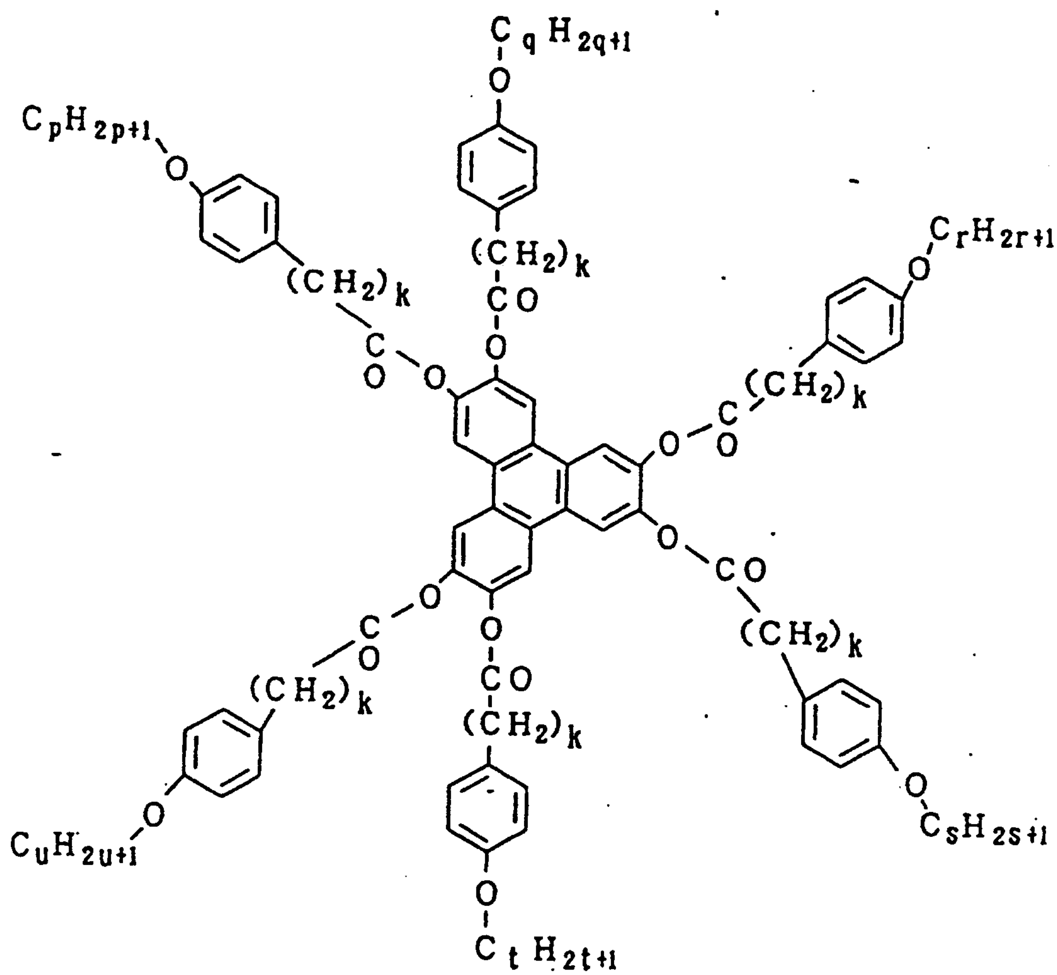
wherein $0 \leq x \leq 6$, $0 \leq y \leq 6$ in the molar ratio, p, q and r are each an integer of 1-18, preferably 3-14.

Composition of the following:



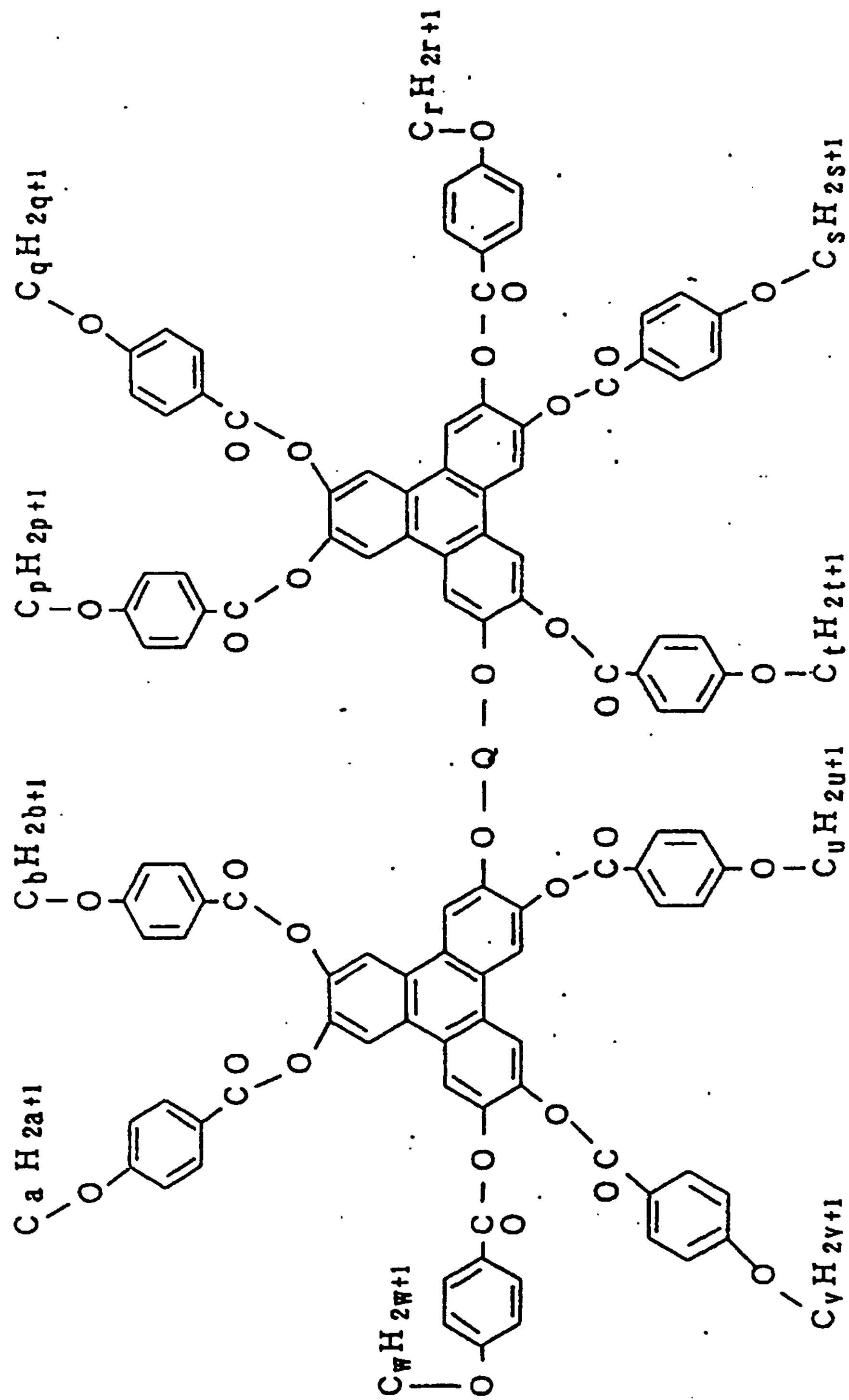
wherein $0 \leq x \leq 6$, $0 \leq y \leq 6$, $0 \leq z \leq 6$ in the molar ratio, p, q and r are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

Composition of the following:

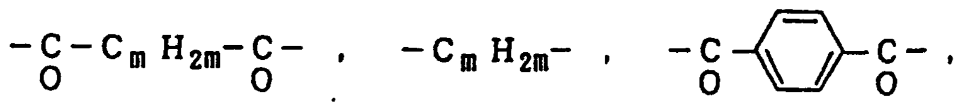


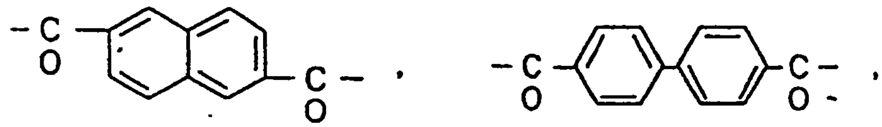
wherein p, q, r, s, t, u, v and w are each an integer of 1-18, preferably 5-14, and k is 1, 2 or 3.

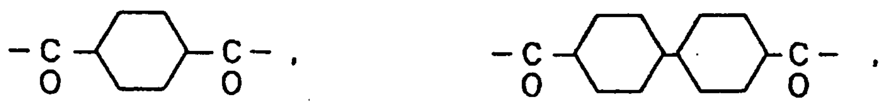
S.

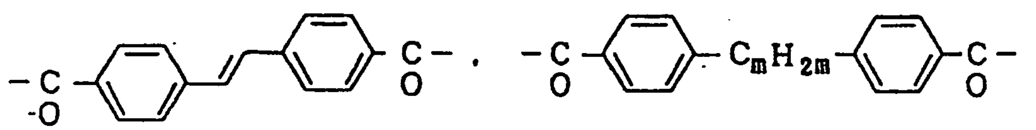


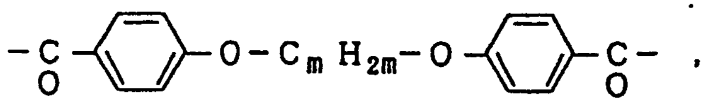
wherein p, q, r, s, t, u, v, w, a and b are each an integer of 1-18, preferably 3-14, and Q is the following:

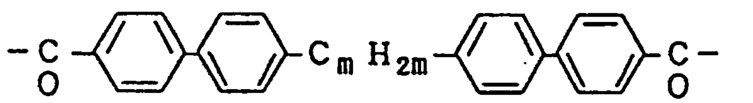


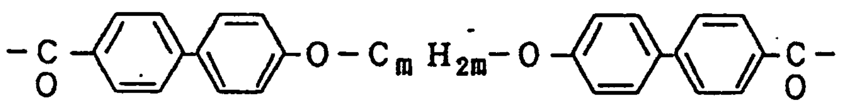


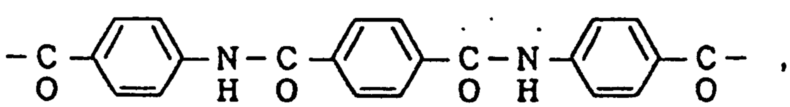


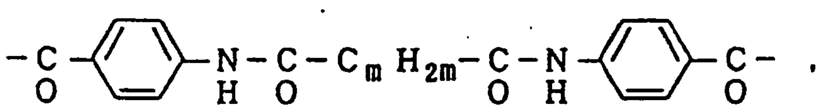


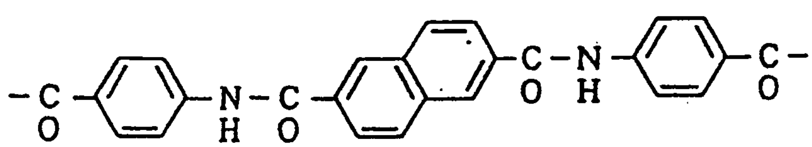








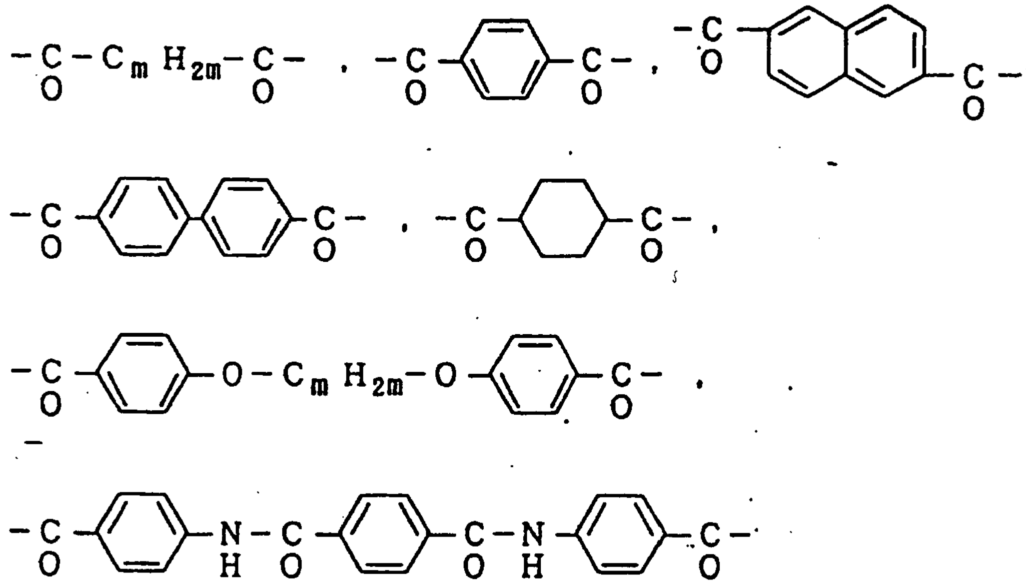




etc.

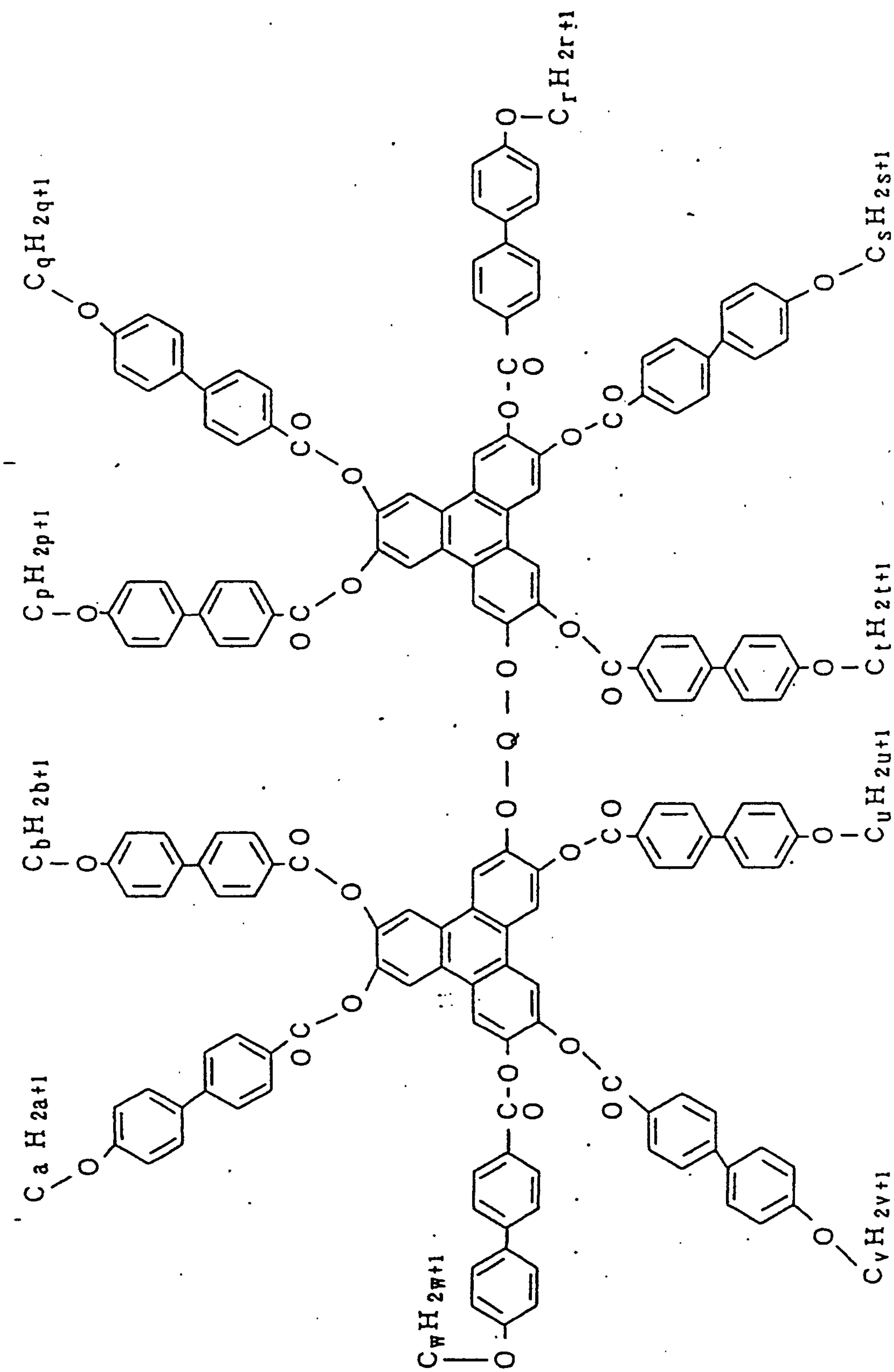
wherein m is an integer of 2-16.

Preferable Q:

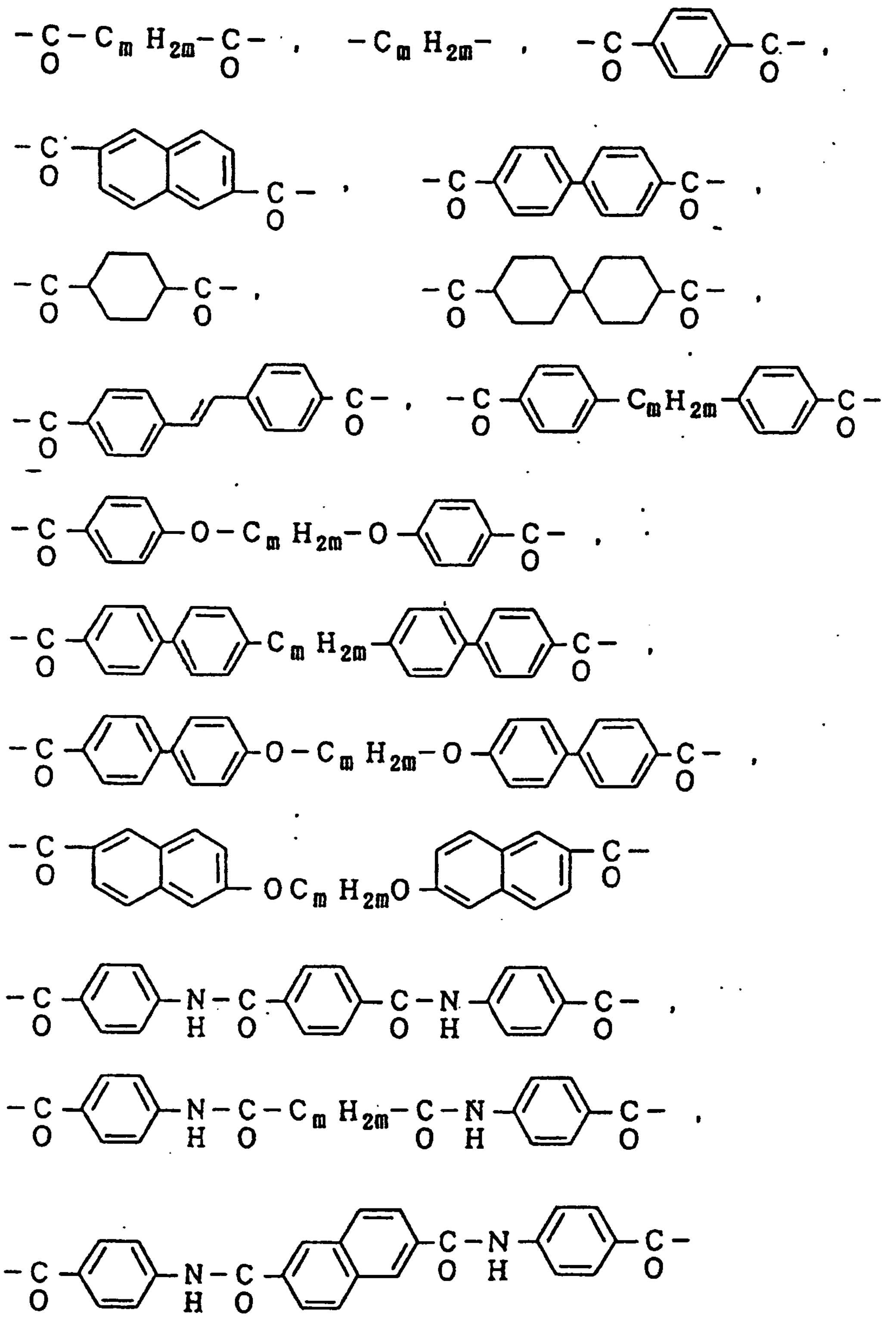


etc.

wherein m is an integer of 2-18, more preferably 4-12.



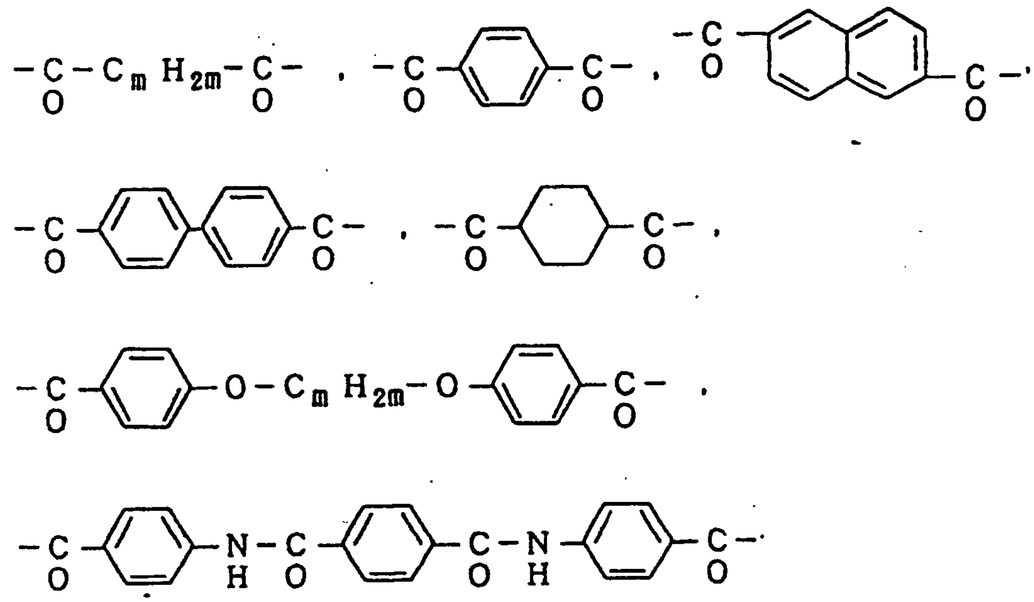
wherein p, q, r, s, t, u, v, w, a and b are each an integer of 1-18, preferably 3-14. Q is the following:



etc.

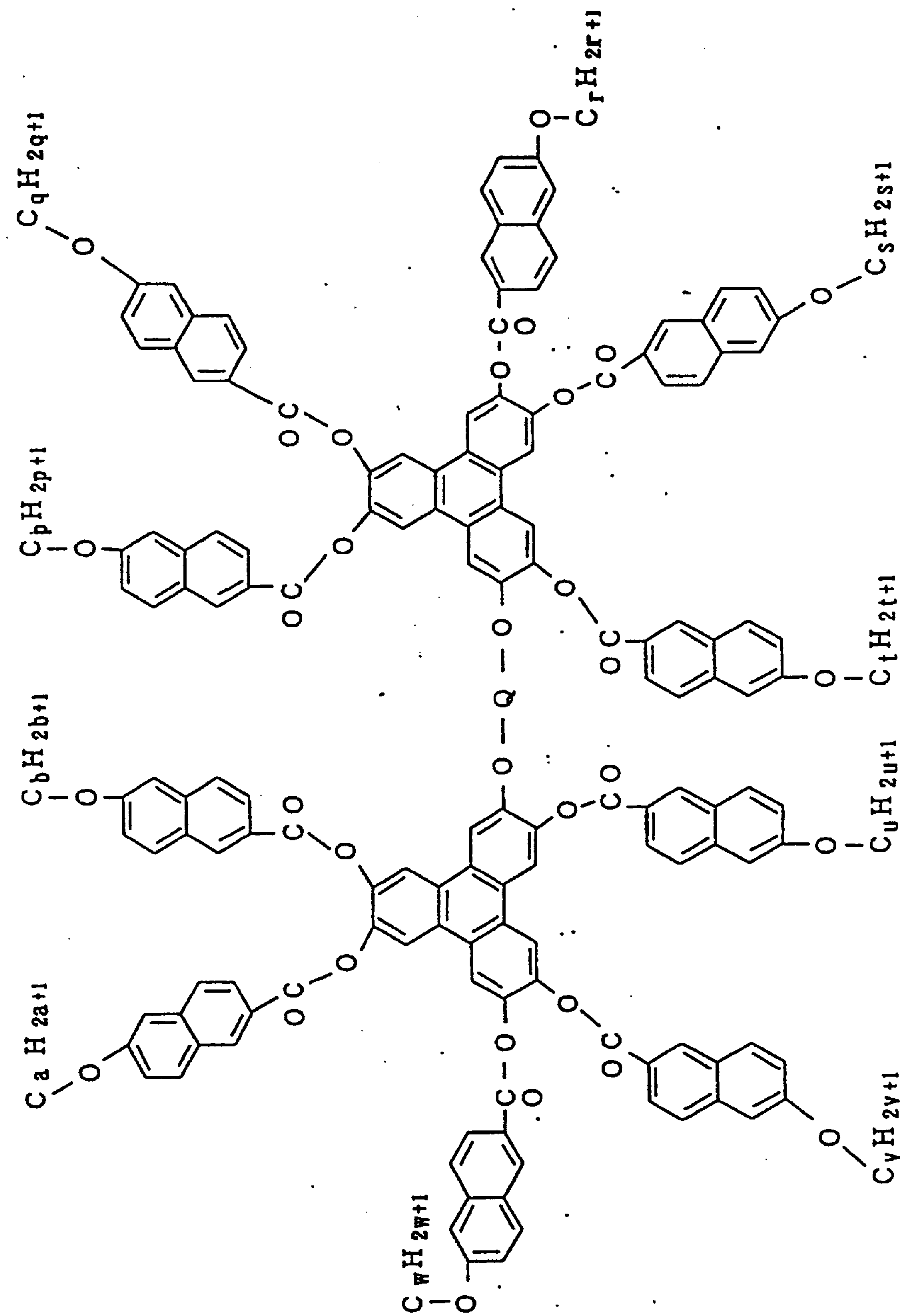
wherein m is an integer of 2-16.

Preferable Q:



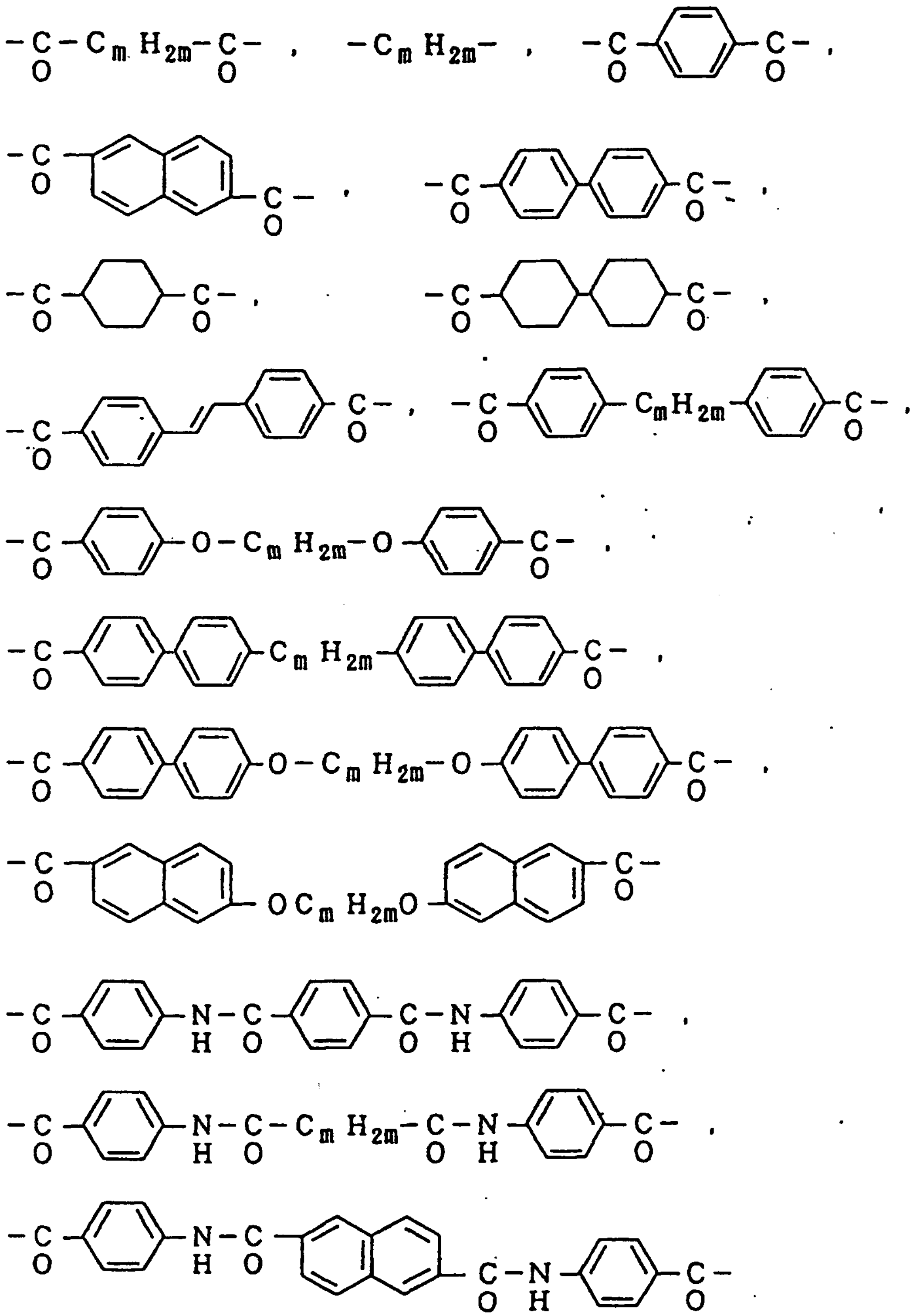
etc.

wherein m is an integer of 2-16, more preferably 4-12.



wherein p, q, r, s, t, u, v, w, a and b are each an integer of 1-18, preferably 3-14.

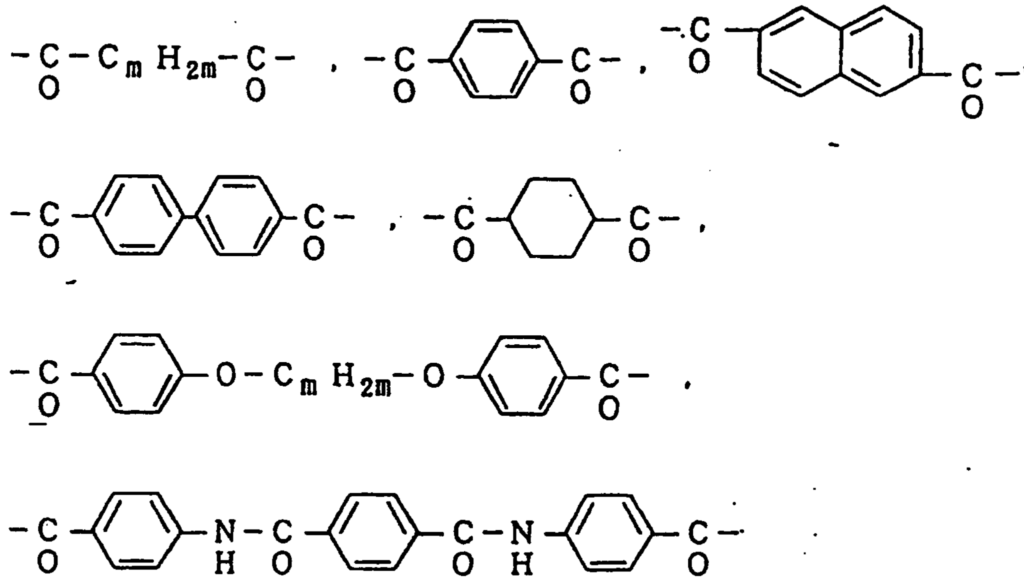
Q is the following:



etc.

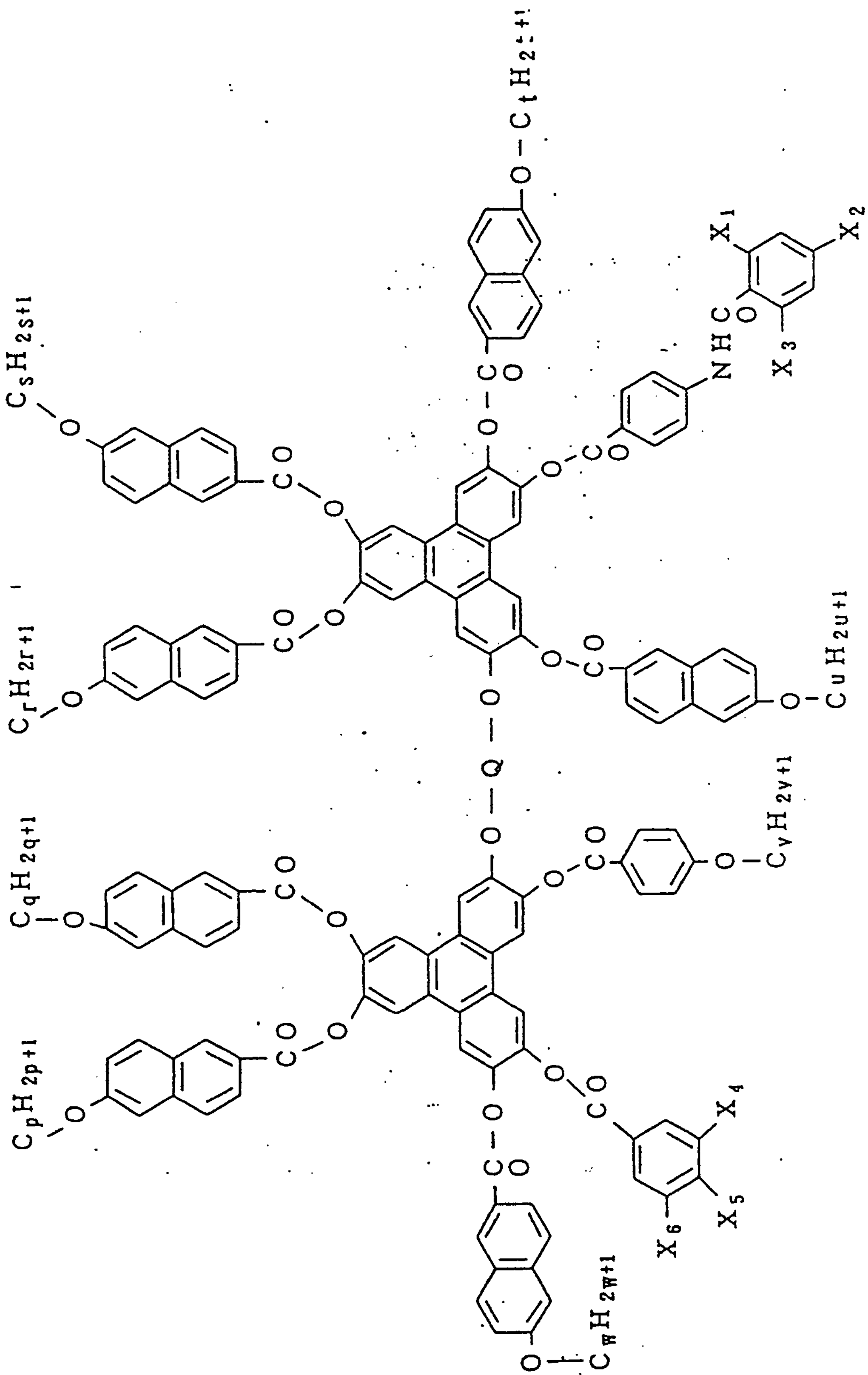
wherein m is an integer of 2-16.

Preferable Q:

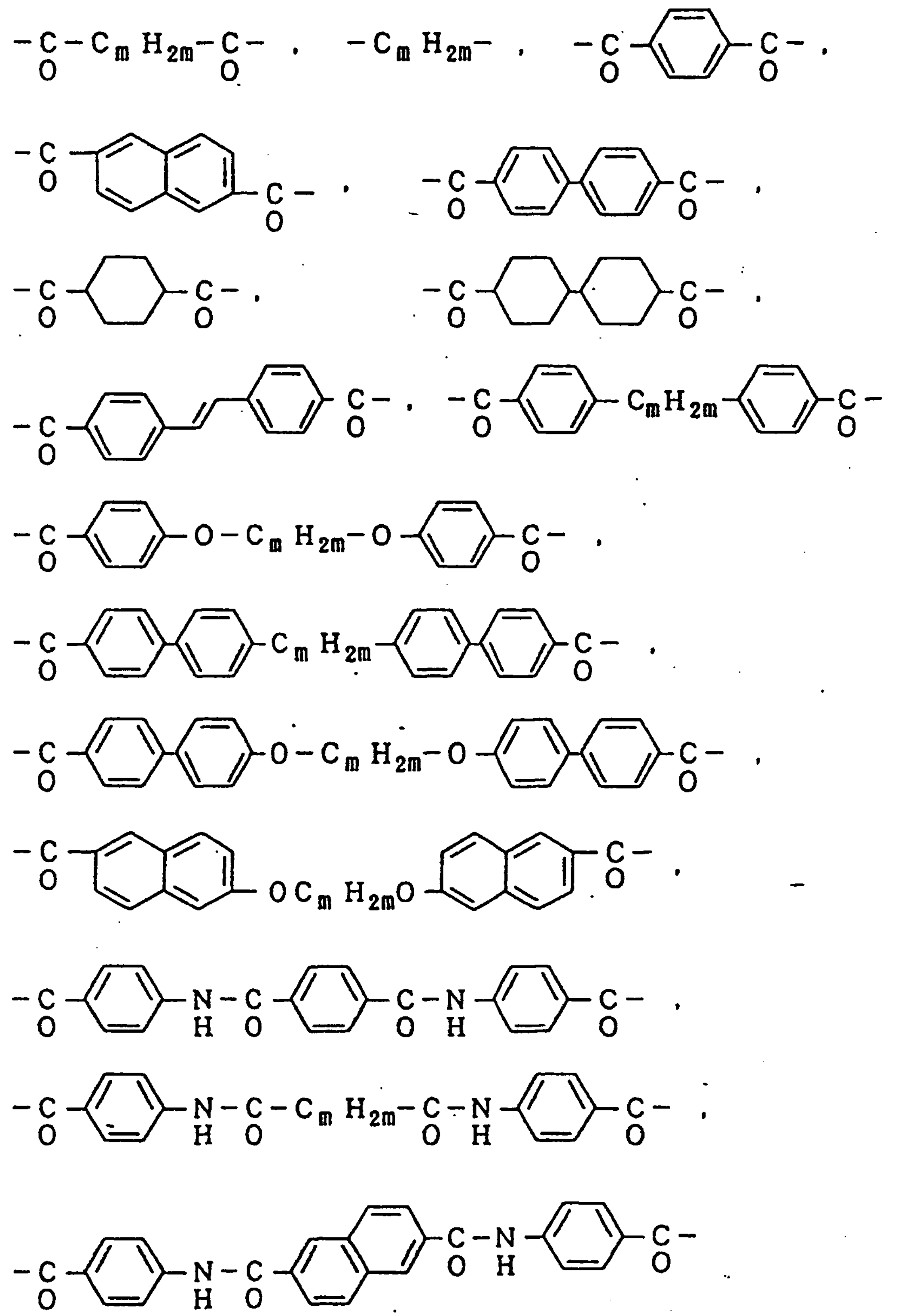


etc.

wherein m is an integer of 2-16, preferably 4-12.



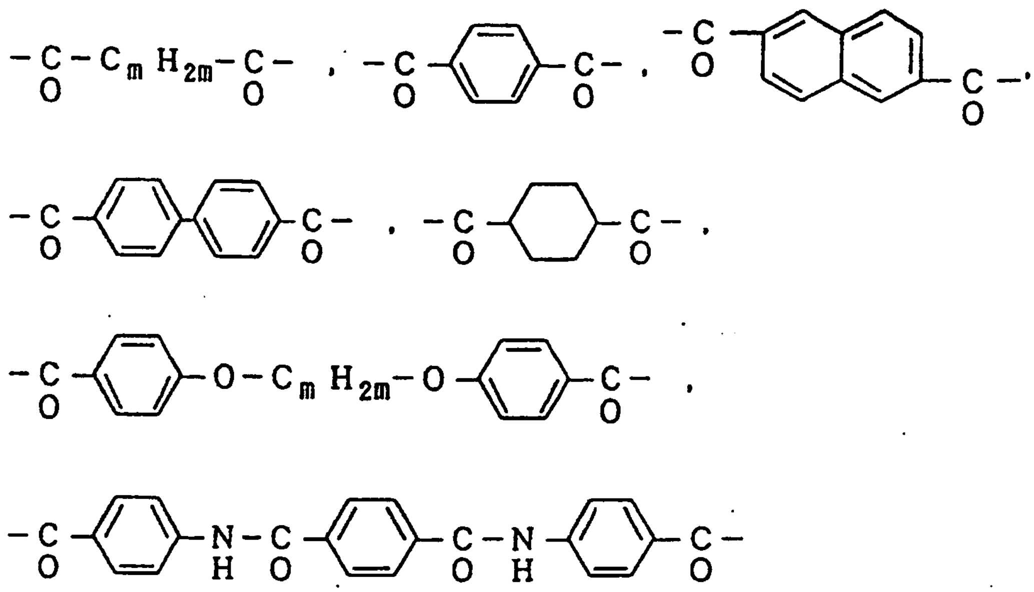
wherein p, q, r, s, t, u, v and w are each an integer of 1-18, preferably 3-14 X_1-X_6 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



etc.

wherein m is an integer of 2-16.

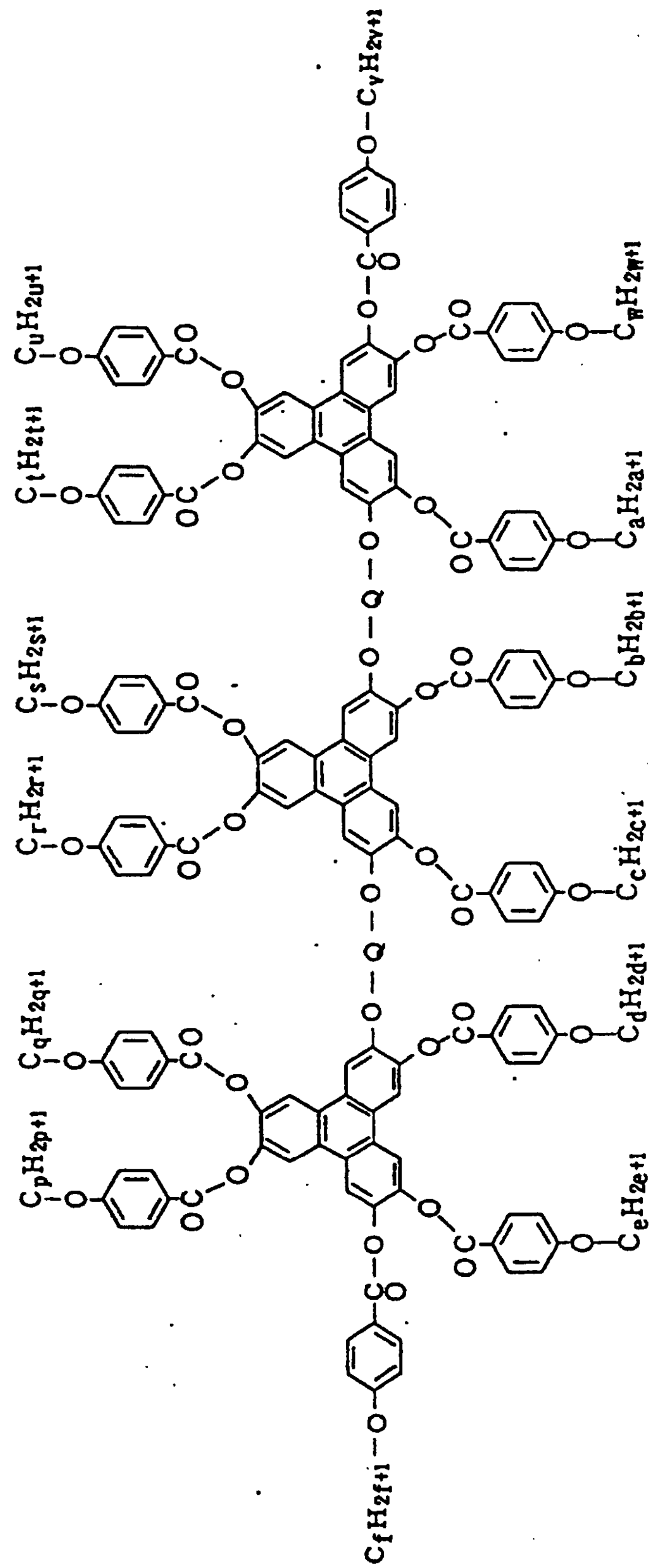
Preferable Q:



etc.

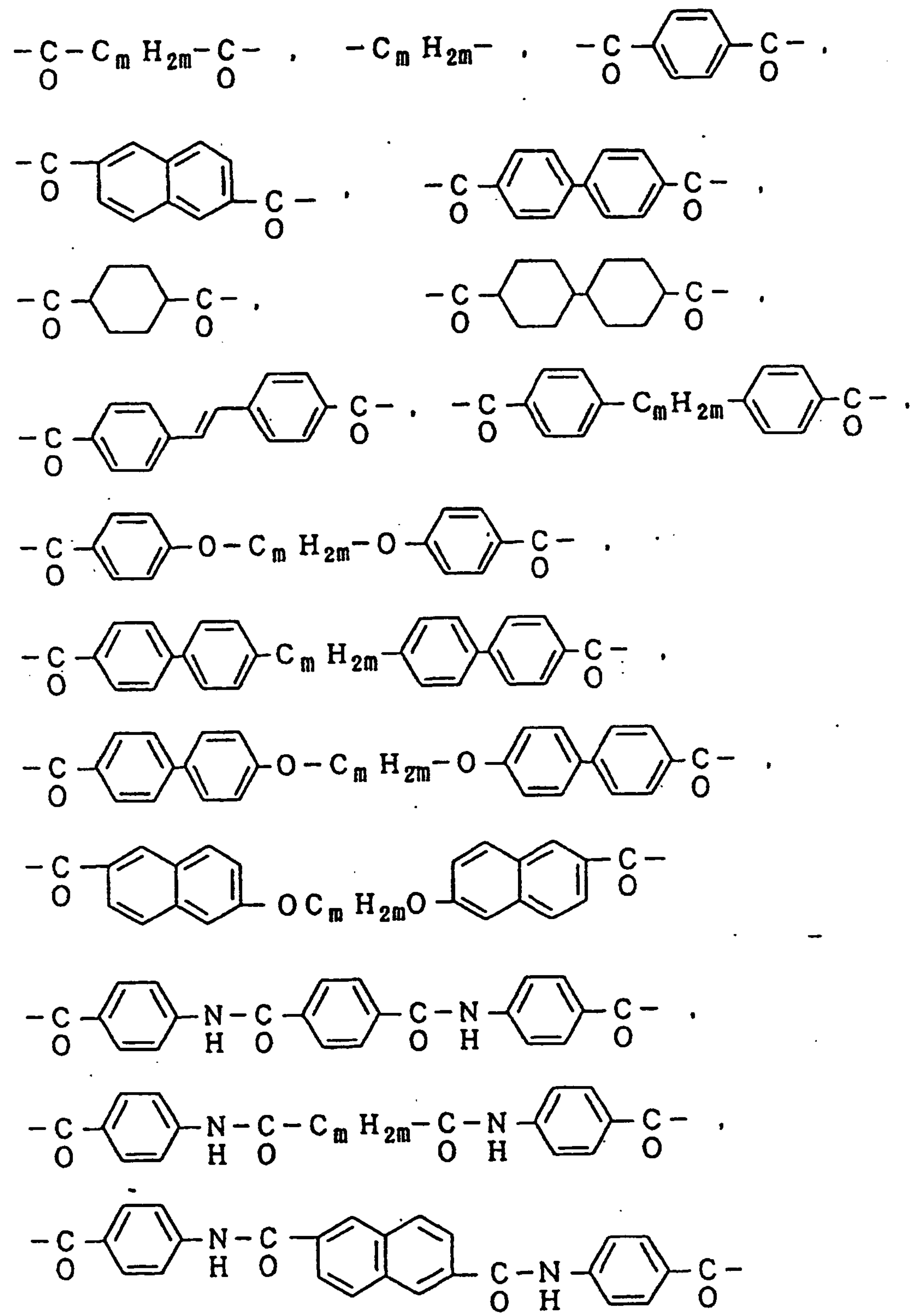
wherein m is an integer of 2-16, preferably 4-12.

6



wherein p, q, r, s, t, u, v, w, a, b, c, d, e and f are each an integer of 1-18, preferably 3-14.

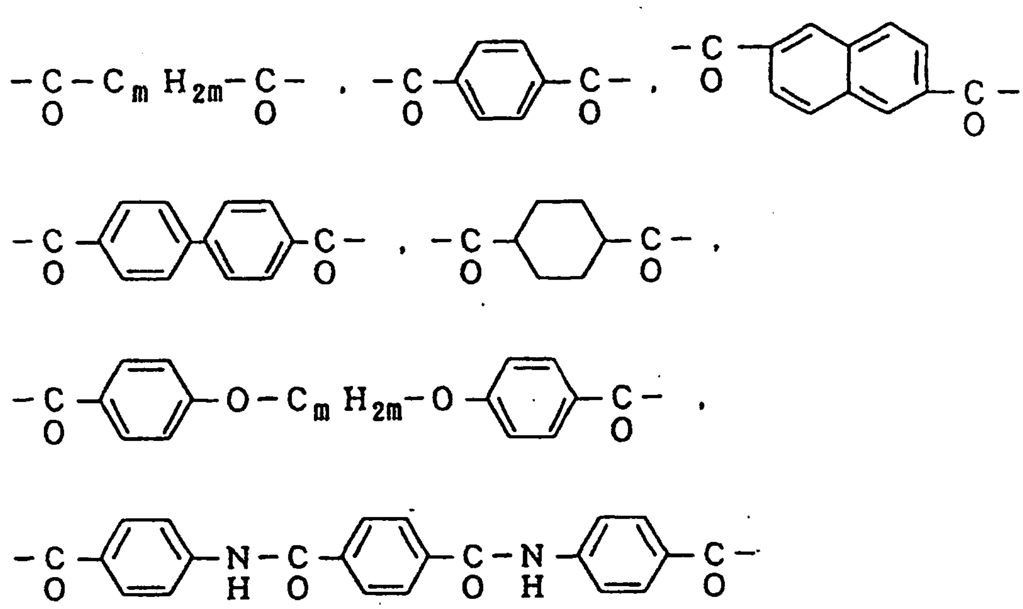
Q is the following:



etc.

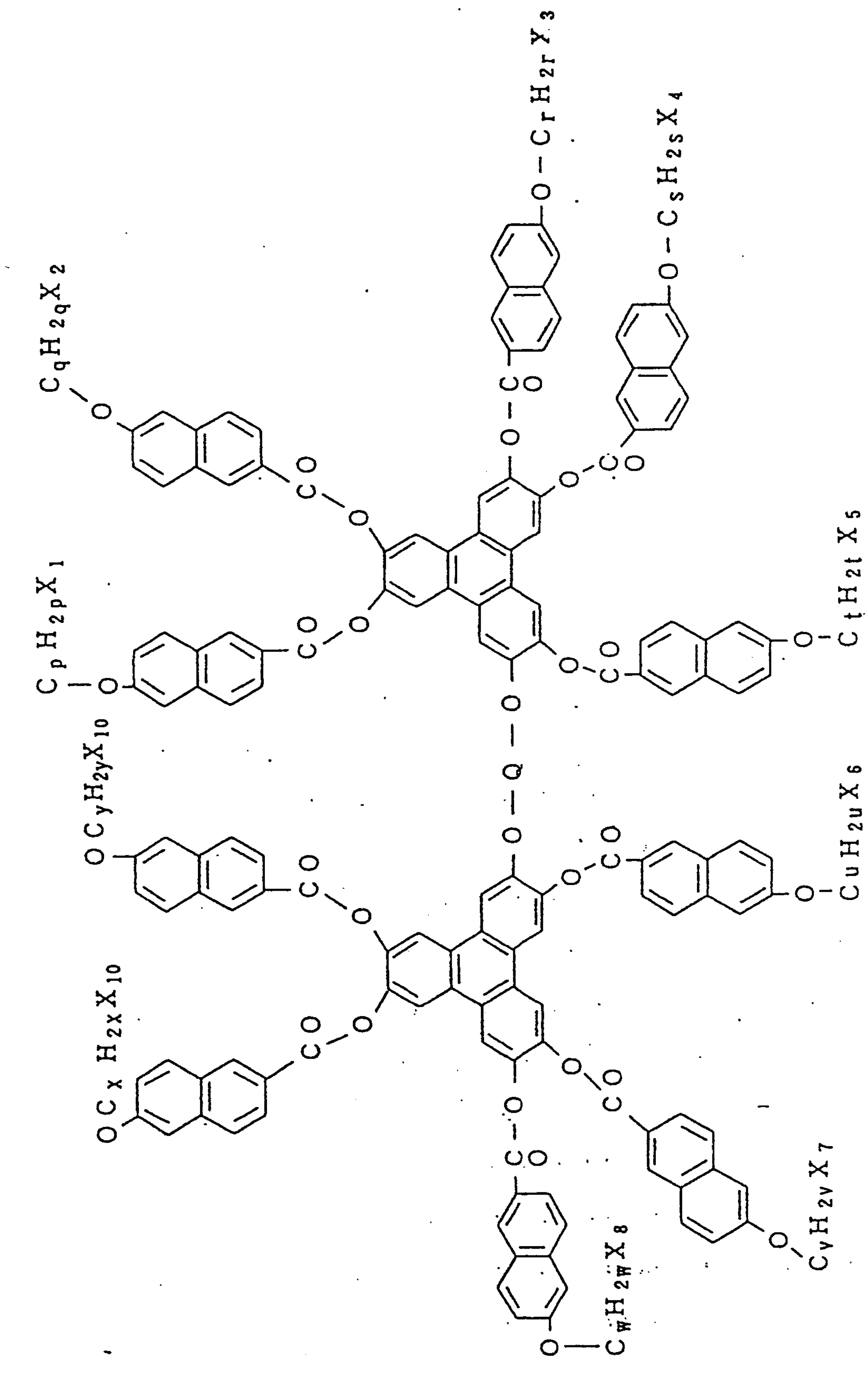
wherein m is an integer of 2-16.

Preferable Q:



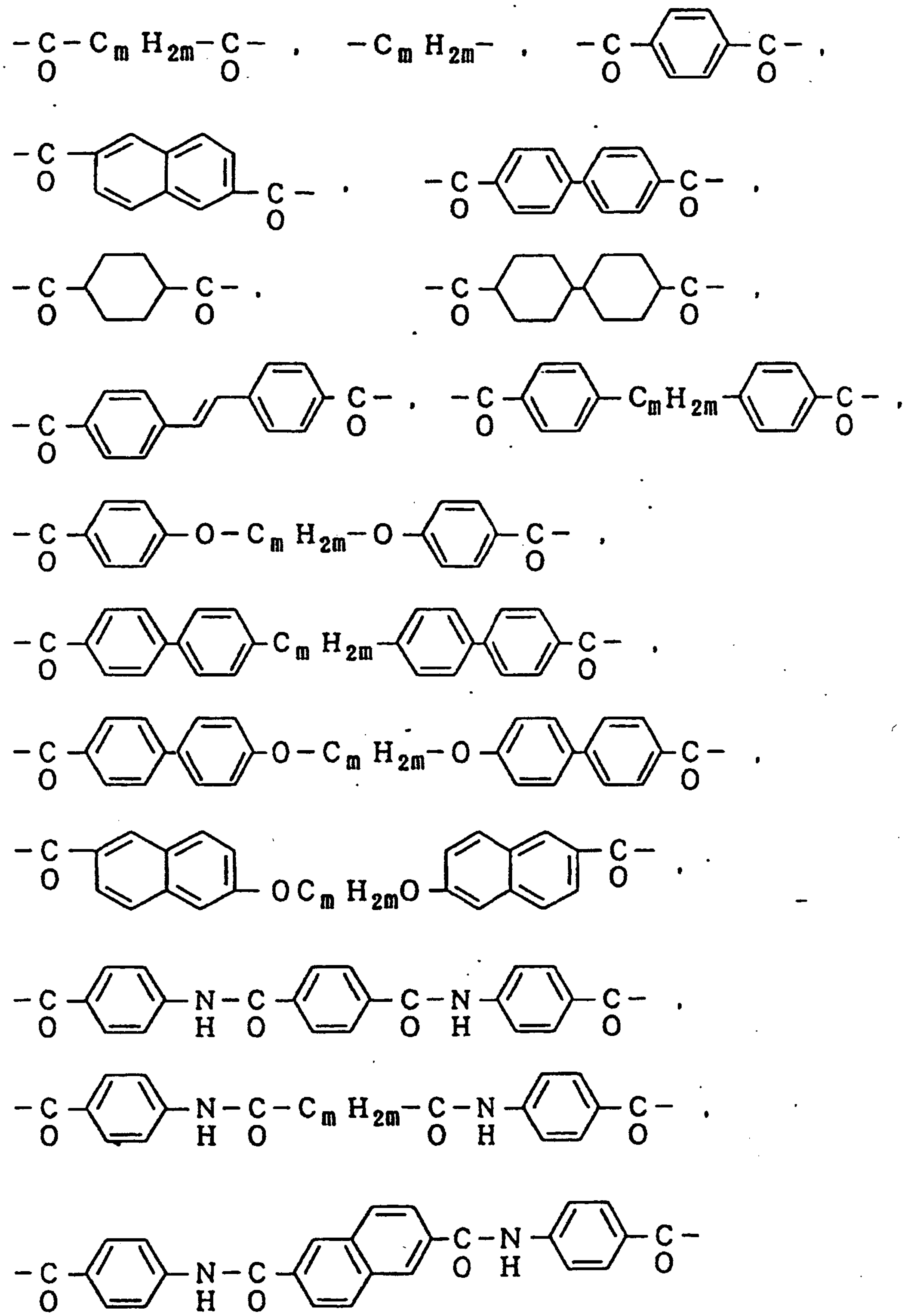
etc.

wherein m is an integer of 2-16, preferably 4-12.



wherein p, q, r, s, t, u, v, w, x and y are each an integer of 1-18, preferably 3-14, X_1-X_{10} are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

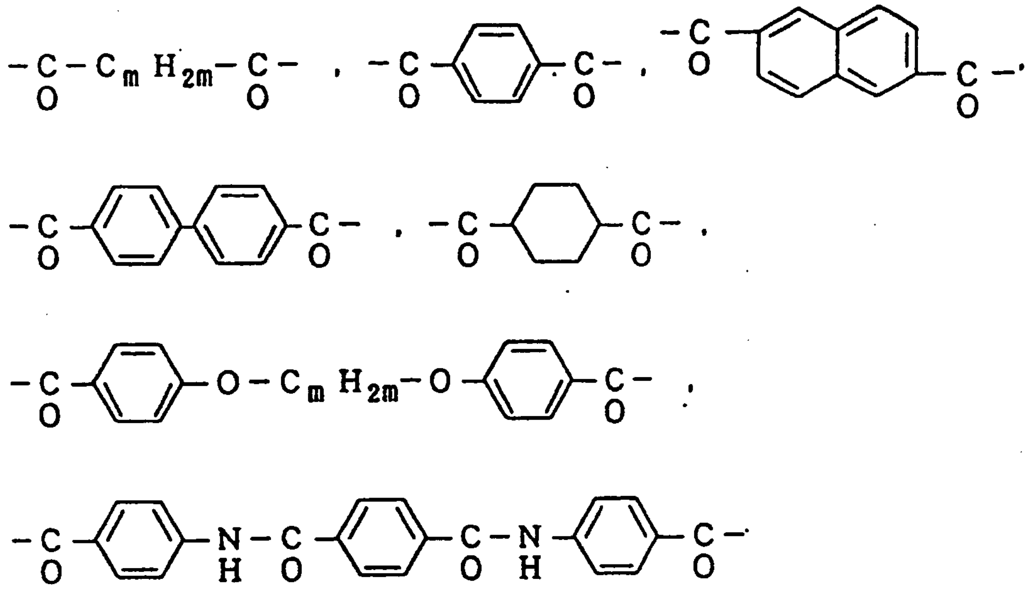
Q is the following:



etc.

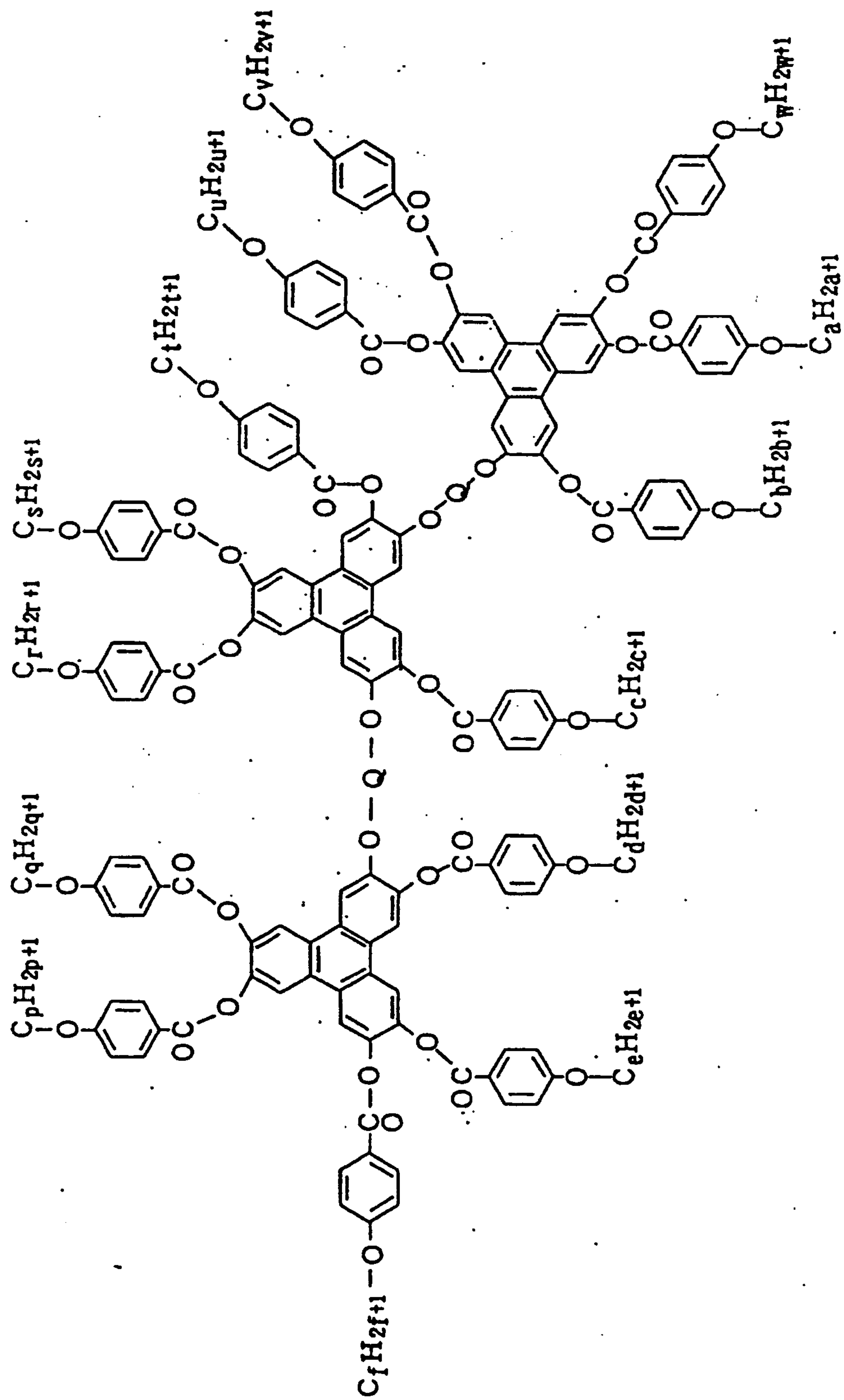
wherein m is an integer of 2-16.

Preferable Q:



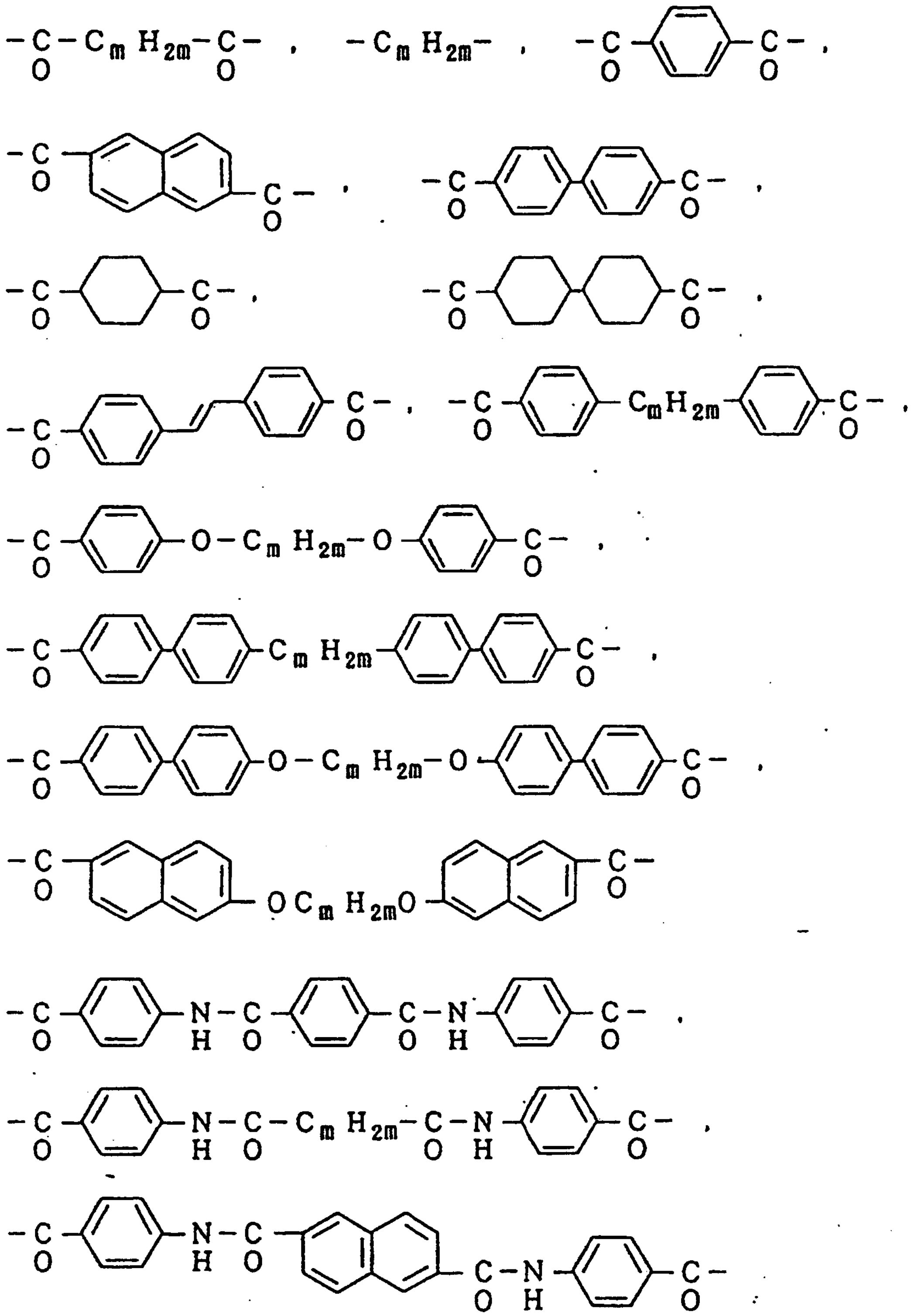
etc.

wherein m is an integer of 2-16, preferably 4-12.



wherein p, q, r, s, t, u, v, w, a, b, c, d, e and f are each an integer of 1-18, preferably 3-14.

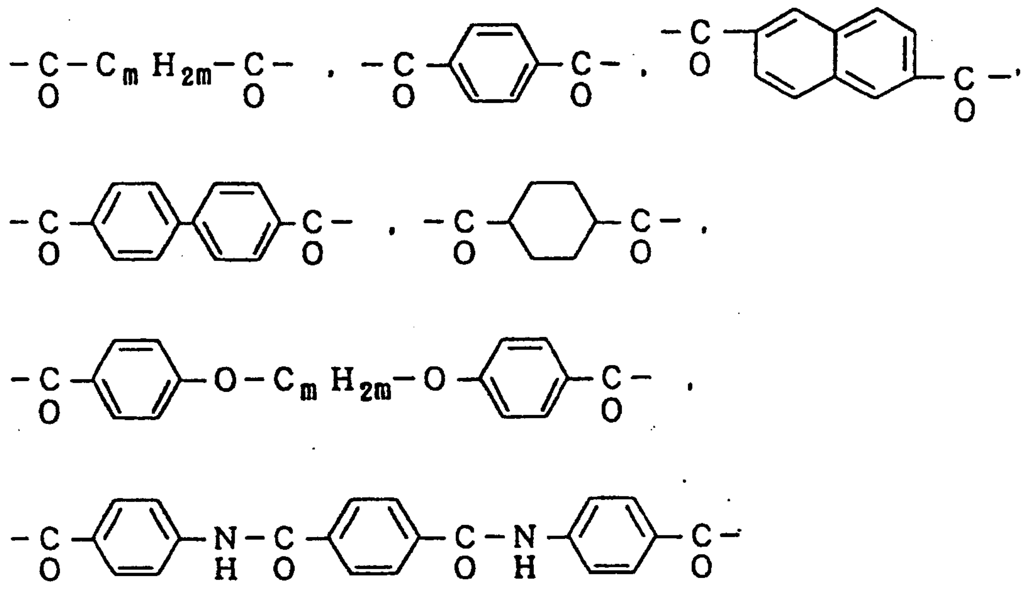
Q is the following:



etc.

wherein m is an integer of 2-16.

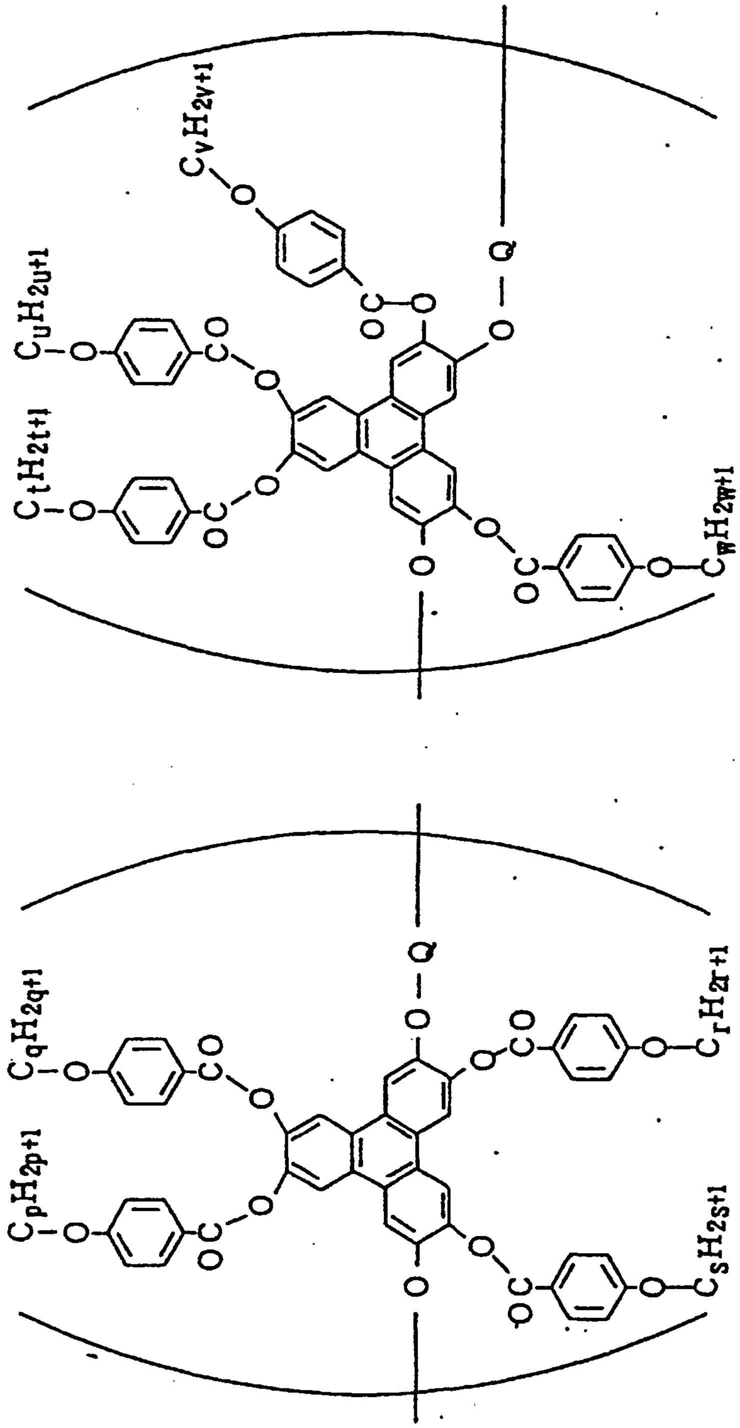
Preferable Q:



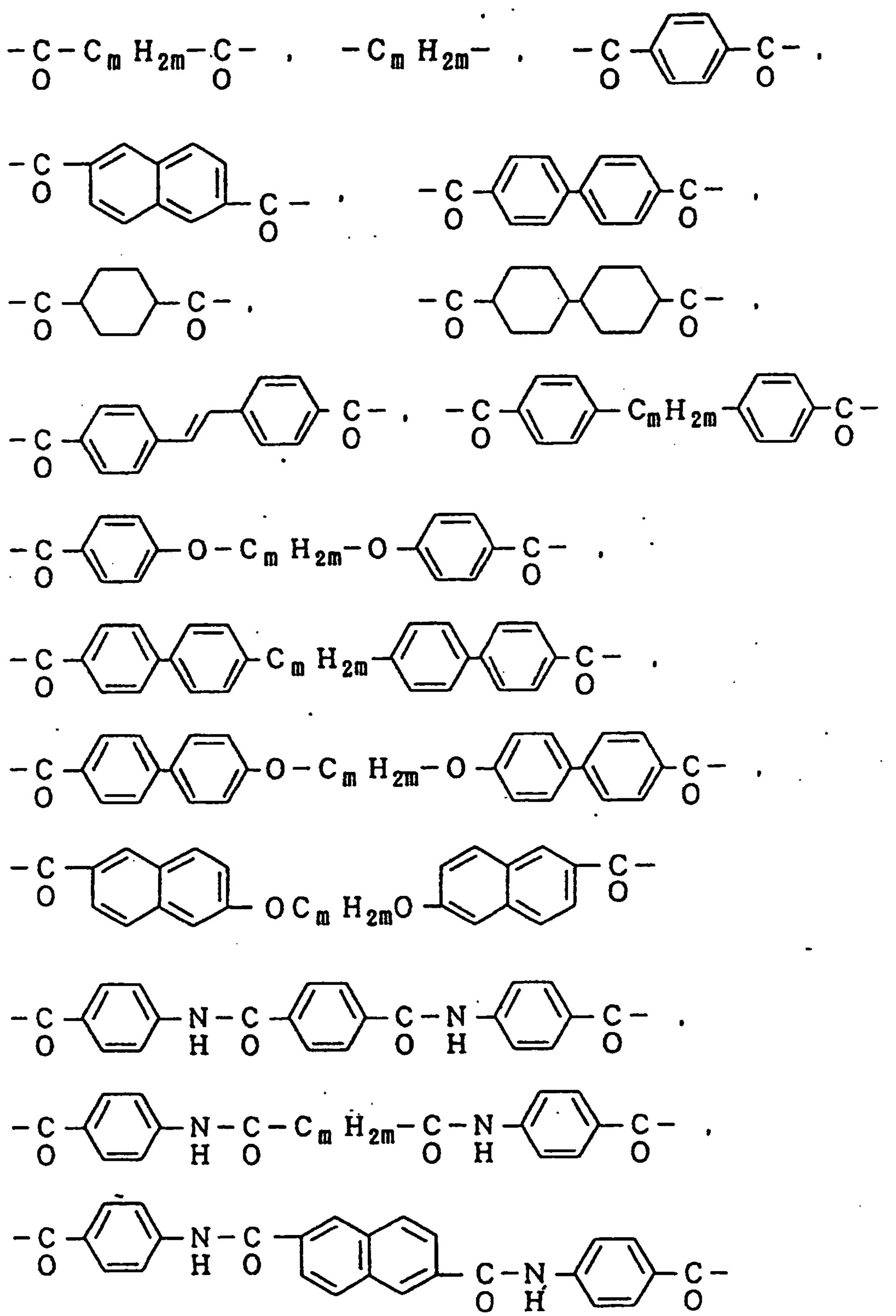
etc.

wherein m is an integer of 2-16, preferably 4-12.

Polymer represented by the following:



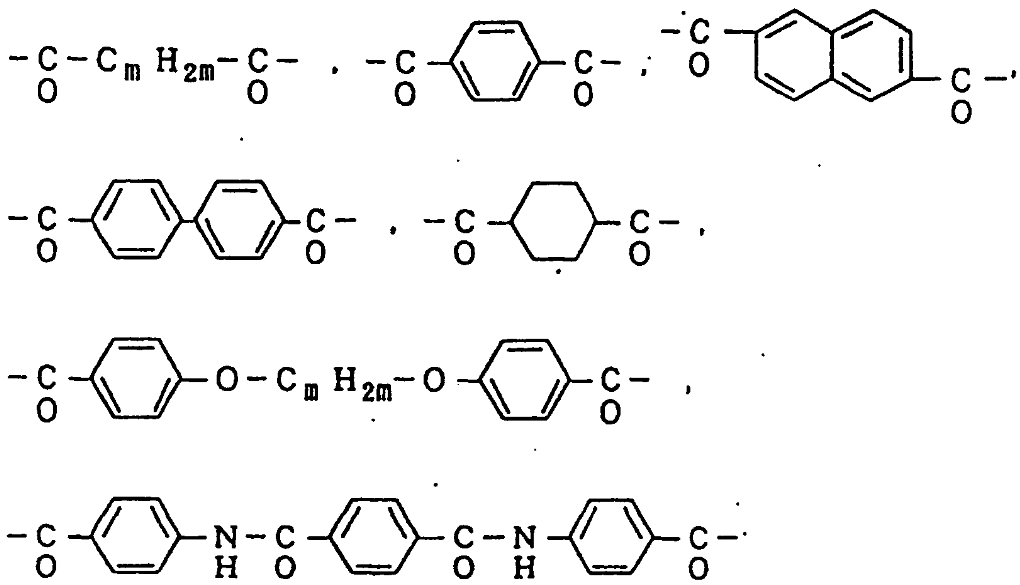
wherein p, q, r, s, t, u, v and w are each an integer of 1-18, preferably 3-14, and the average molecular weight is 5,000 - 100,000.
Q is the following:



etc.

wherein m is an integer of 2-16.

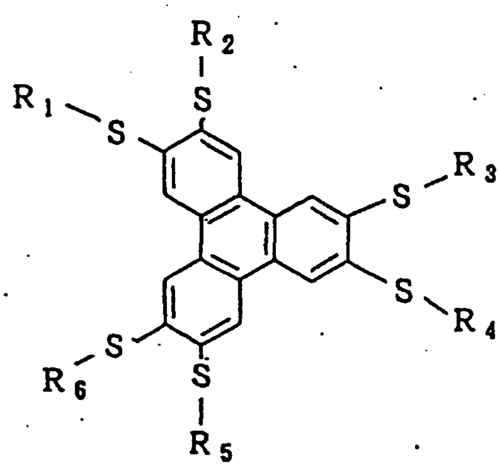
Preferable Q:



etc.

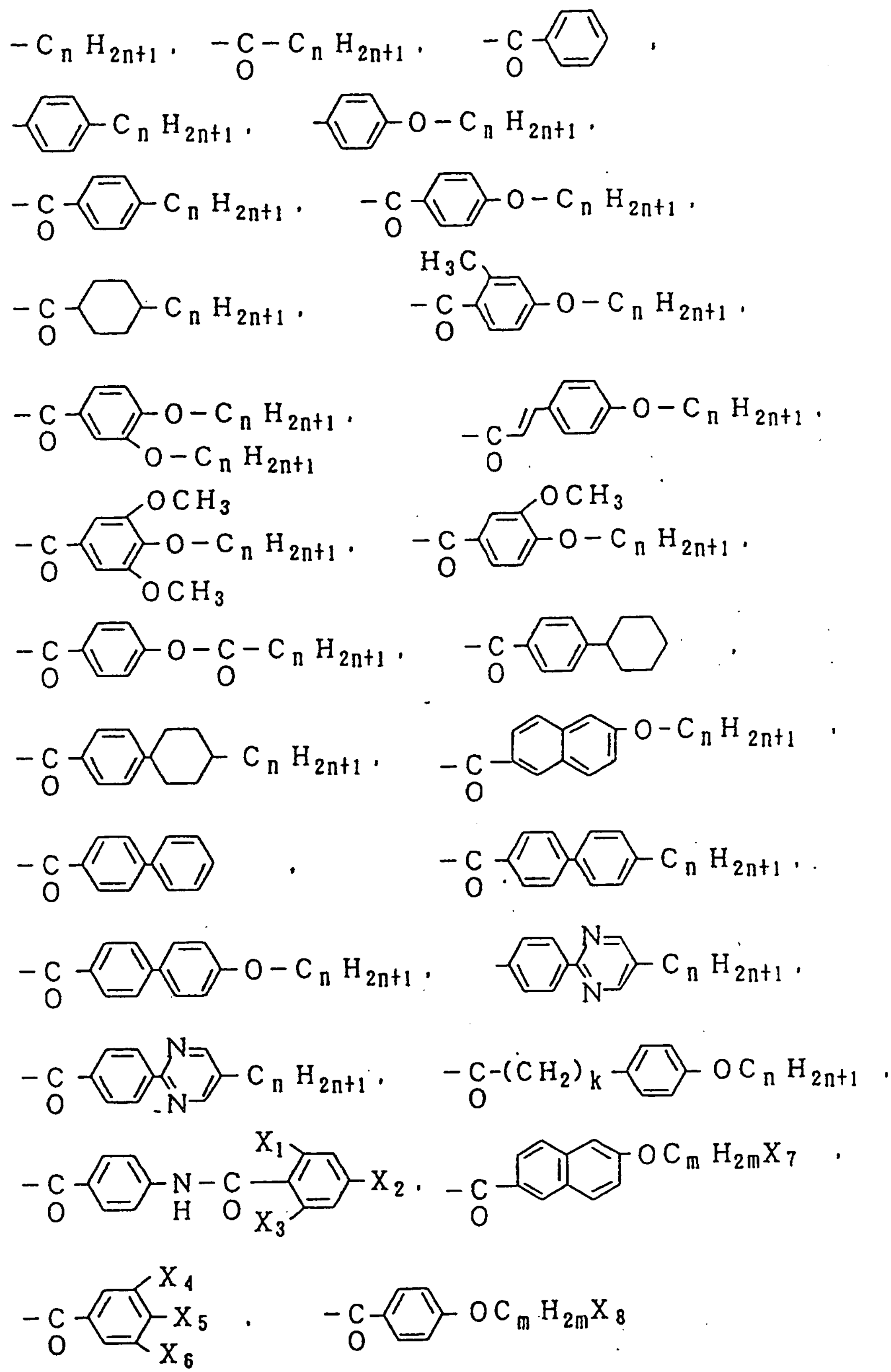
wherein m is an integer of 2-16, preferably 4-12.

[Structural formula 6]



wherein R_1 -R_6 are each a monofunctional or bifunctional substituent group selected from the following:

Mono functional substituent groups:

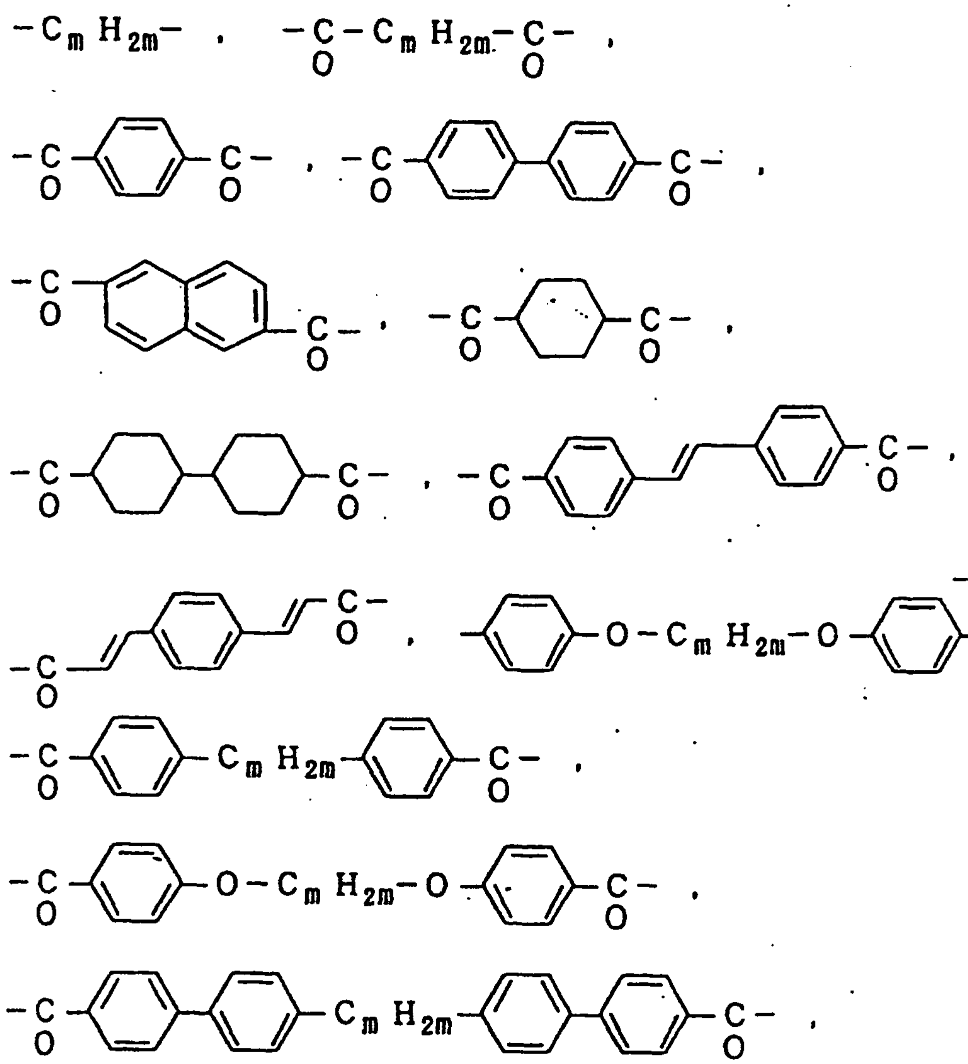


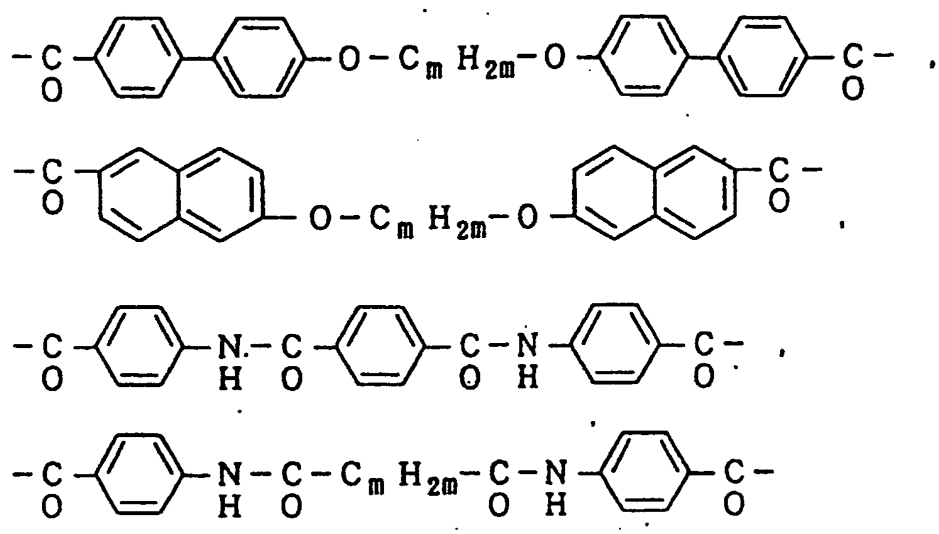
etc.

wherein C_nH_{2n+1} is a linear or branched alkyl group, n is an integer of 1-18, preferably 3-14, X_1-X_8 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl

group, ℓ is an integer of 1-18, preferably 1-10, C_mH_{2m} is a linear or branched alkylene chain, and m is an integer of 1-18, preferably 2-10.

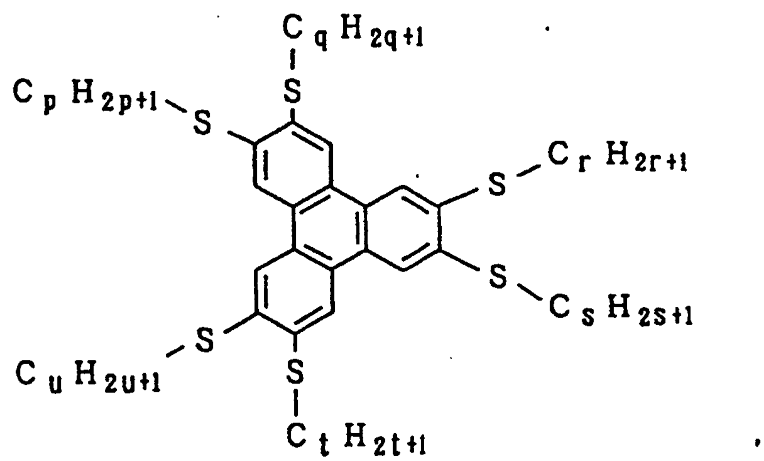
Bifunctional substituent groups:



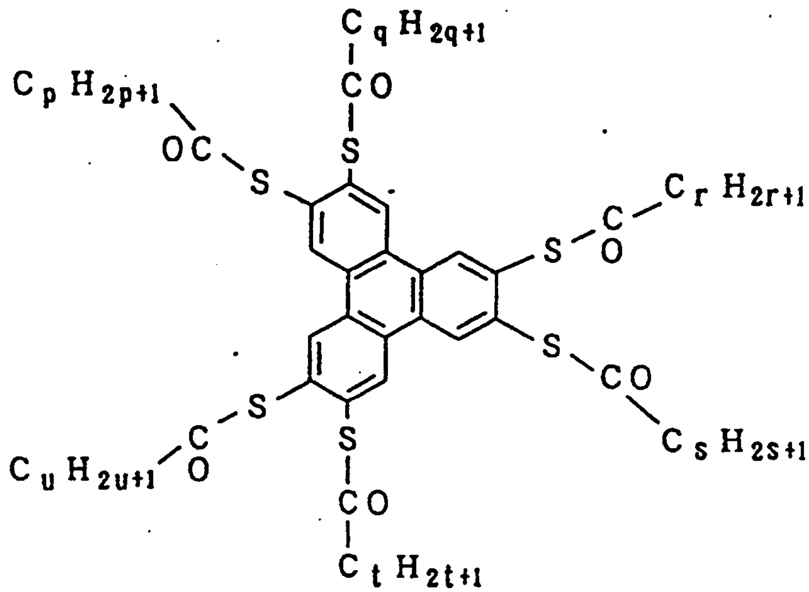


etc.

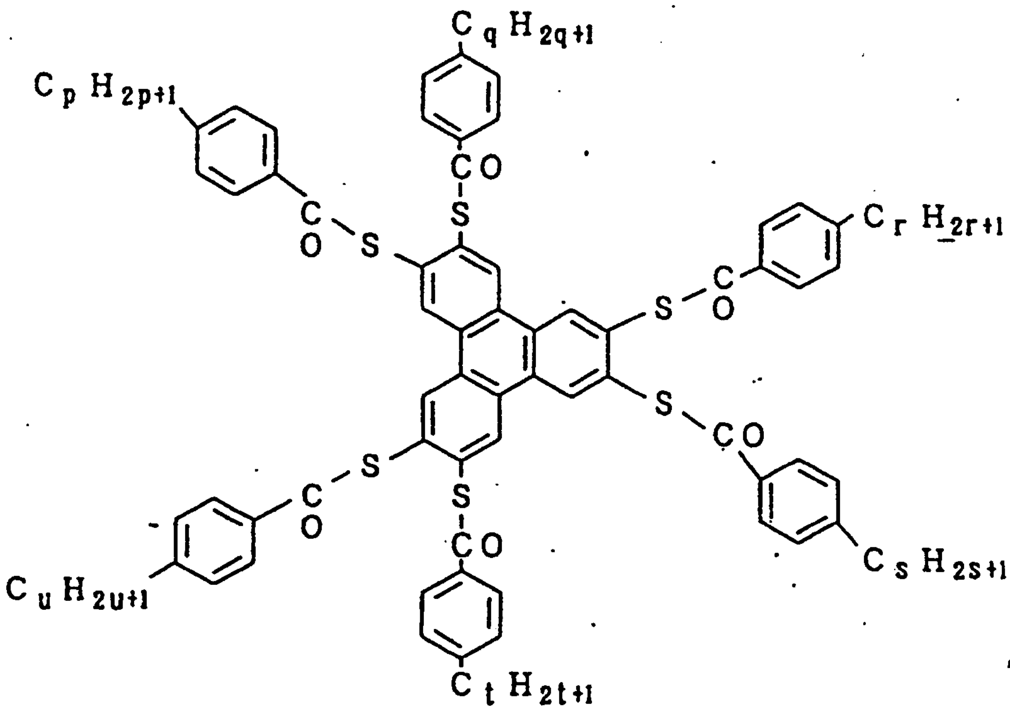
wherein C_mH_{2m} is a linear or branched alkylene group, and m is an integer of 2-16, preferably 4-12. Examples of the concrete structures:



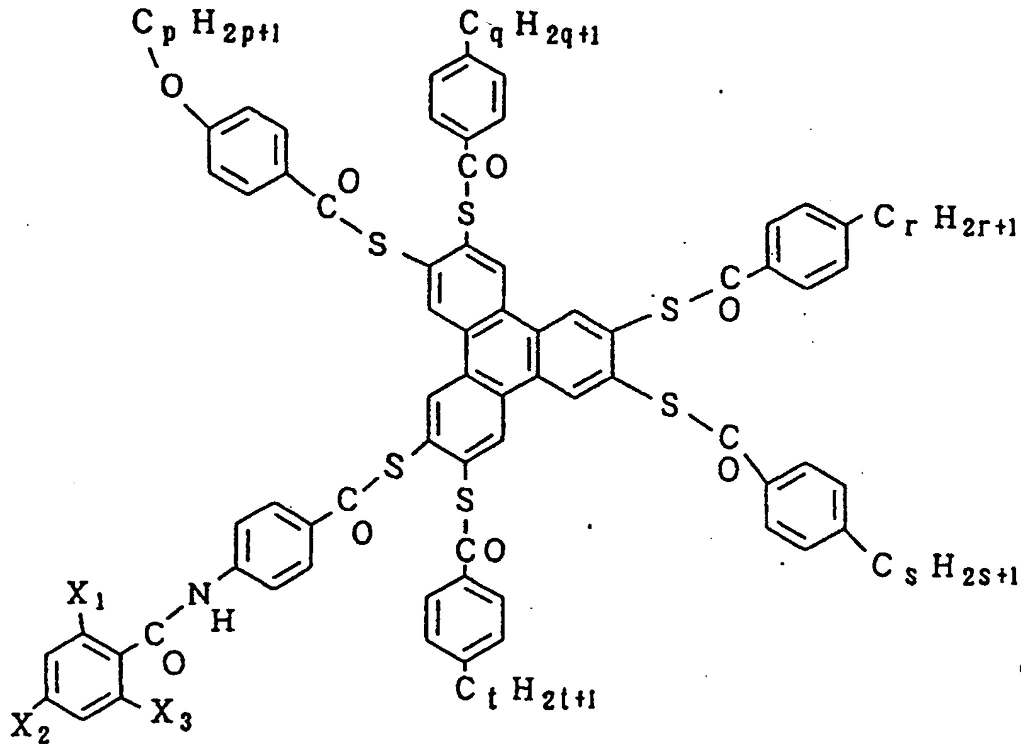
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



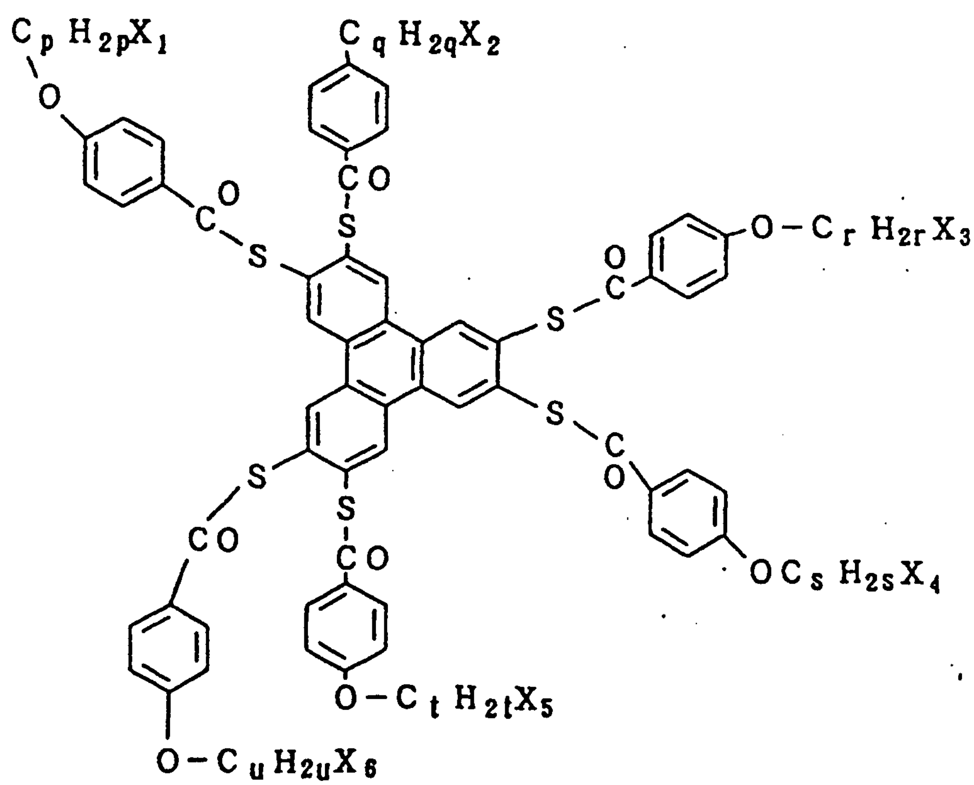
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



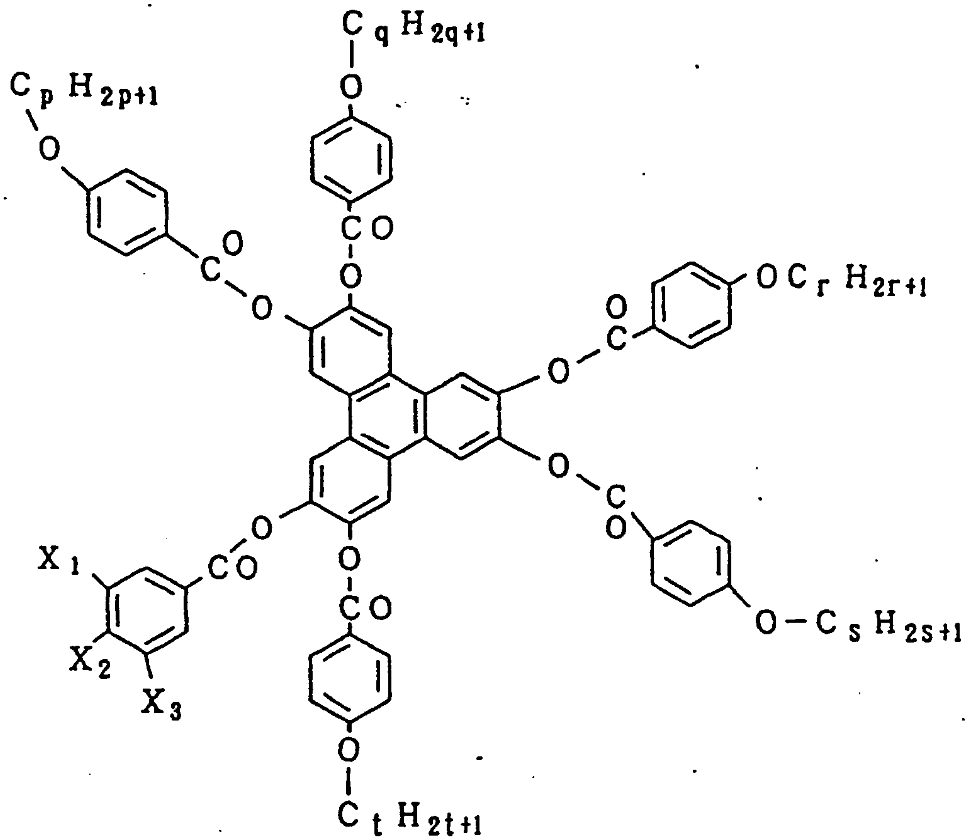
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



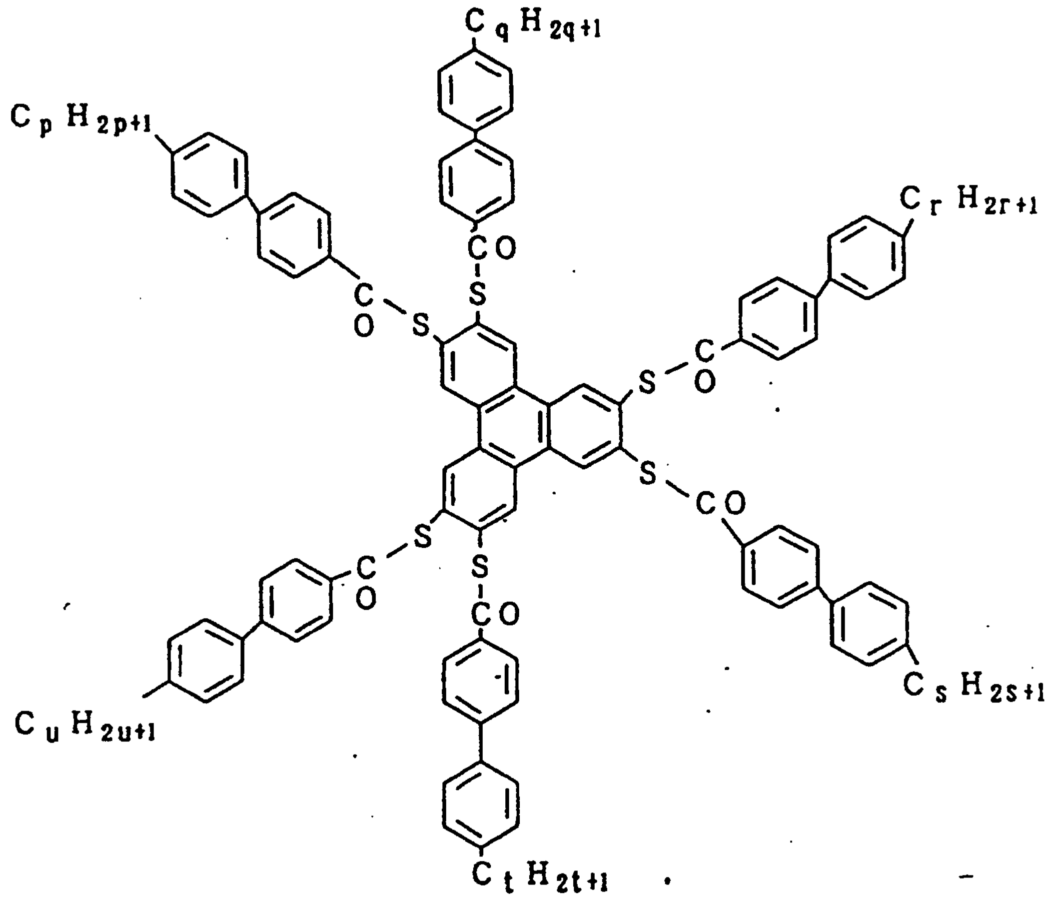
wherein p, q, r, s and t are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



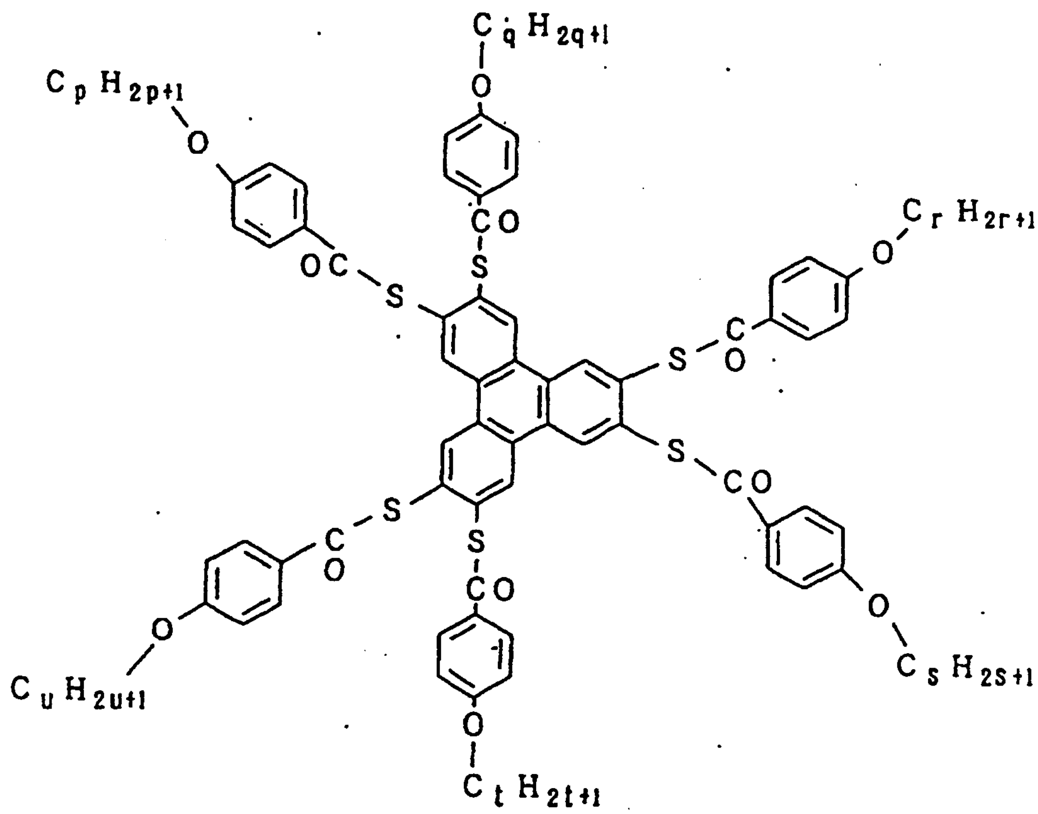
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14, X_1-X_6 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



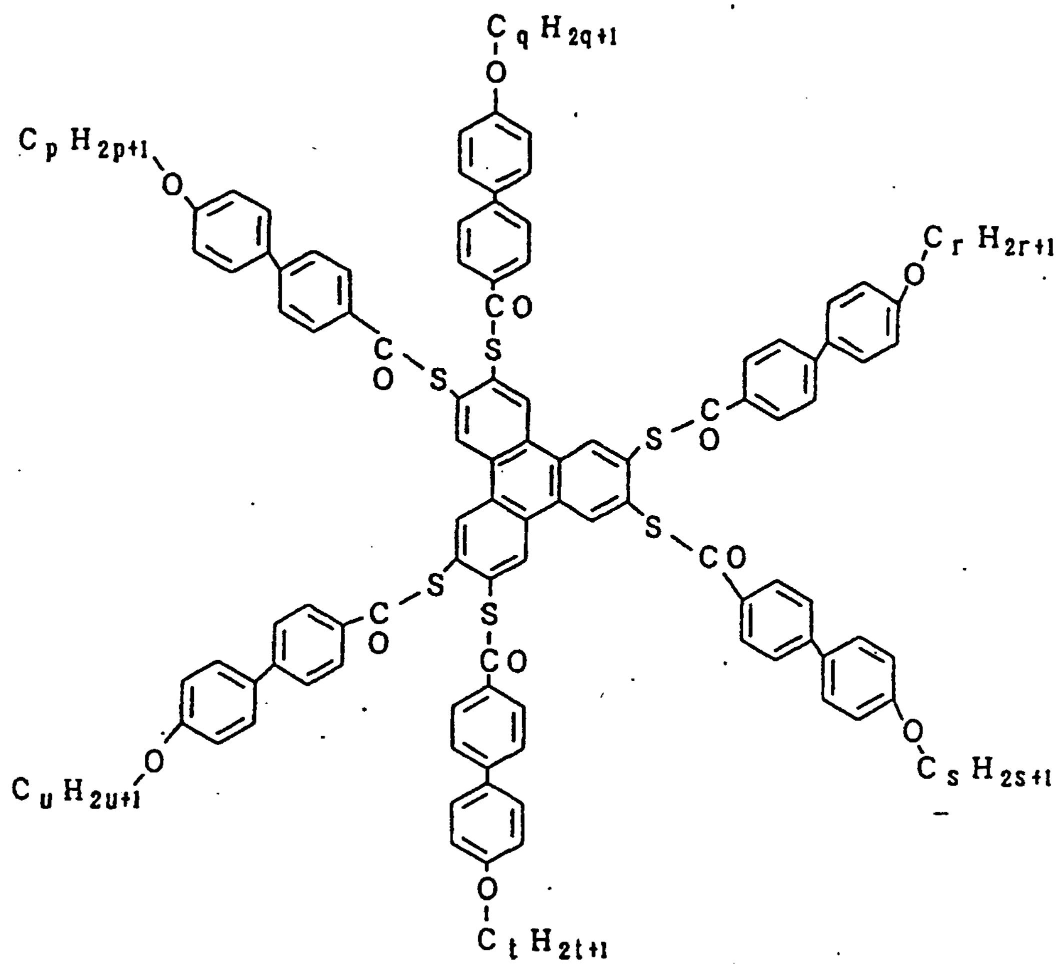
wherein p, q, r, s and t are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



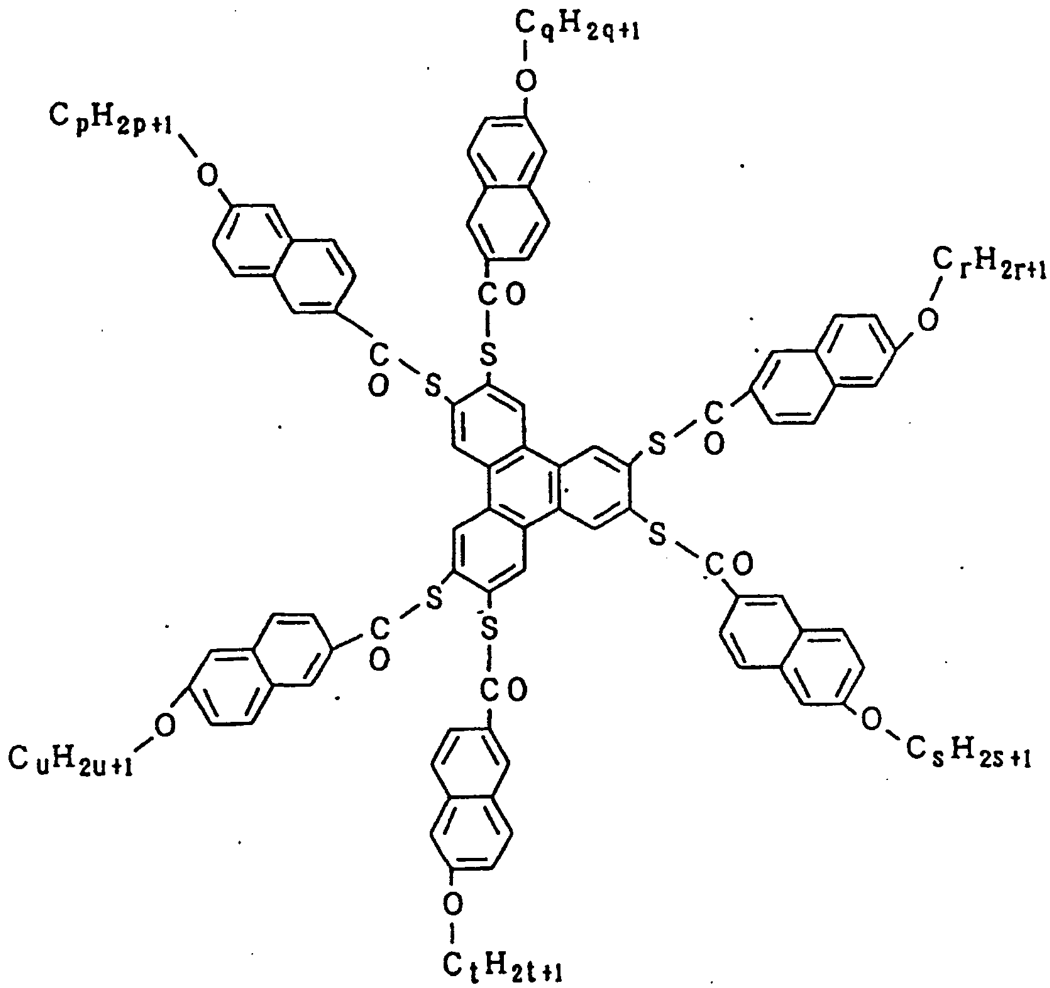
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

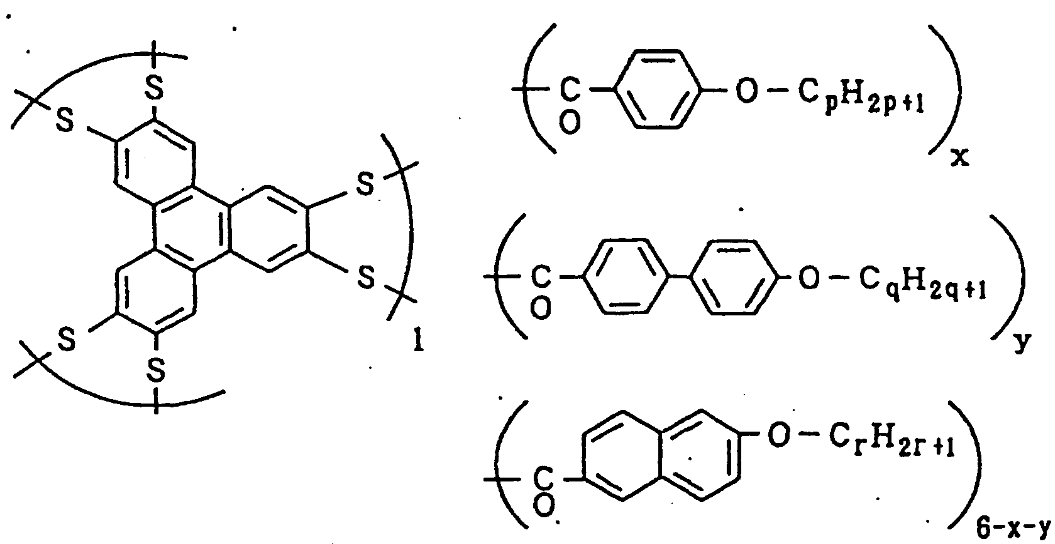


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

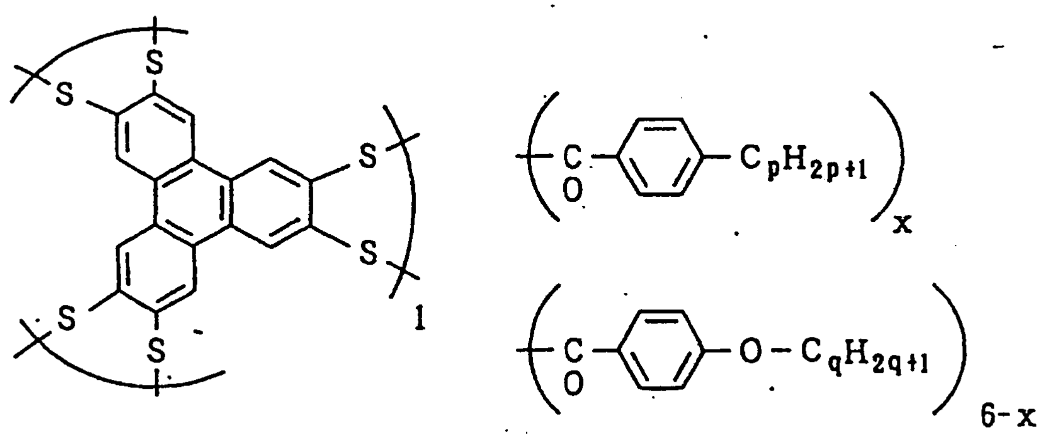


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

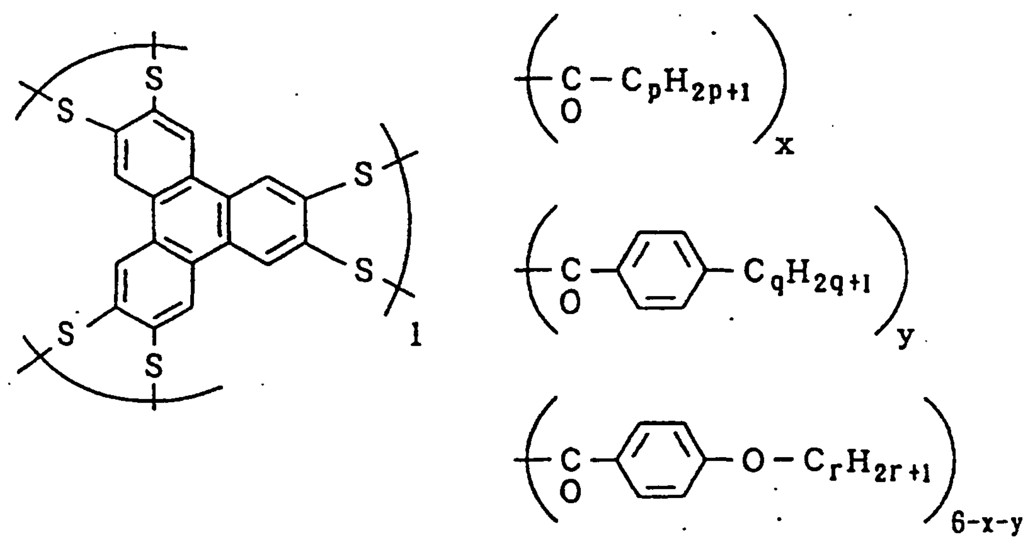
Composition of the following:



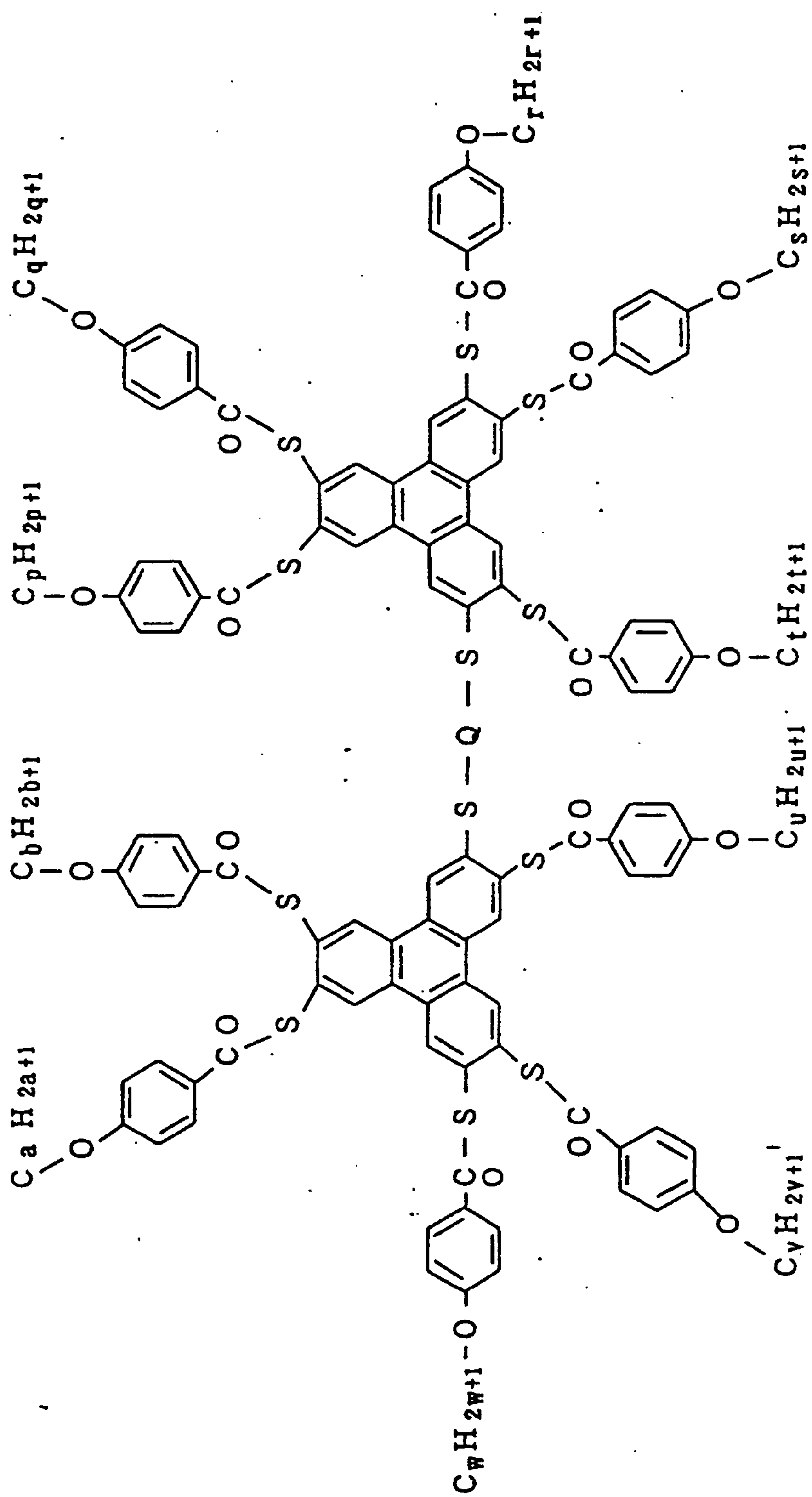
wherein 0≦x≦6, 0≦y≦6 in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14.
Composition of the following:



wherein 0≦x≦6 in the molar ratio, and p and q are each an integer of 1-18, preferably 3-14.
Composition of the following:

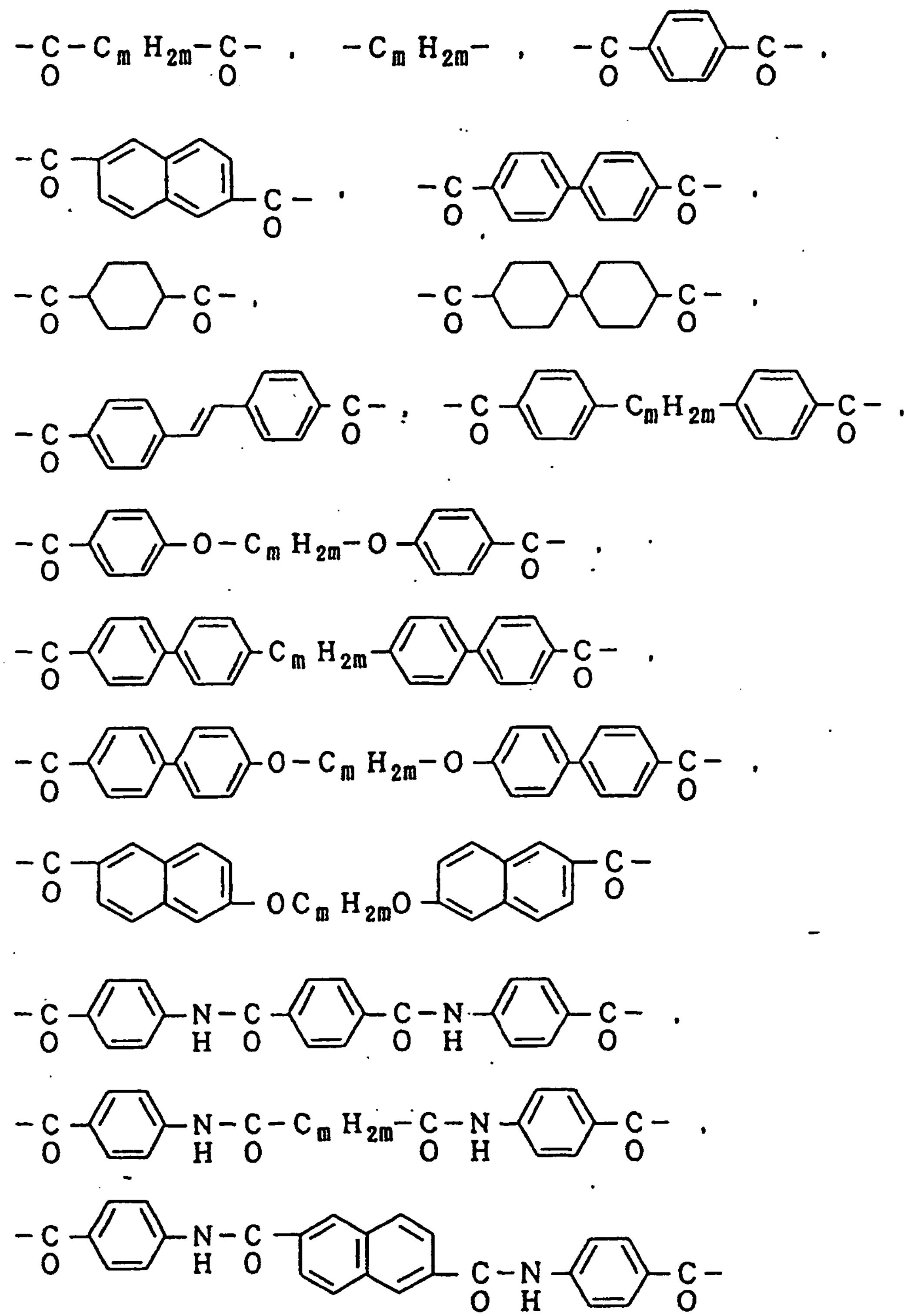


wherein 0≦x≦6, 0≦y≦6 in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14.



wherein p, q, r, s, t, u, v, w, a and b are each an integer of 1-18, preferably 3-14.

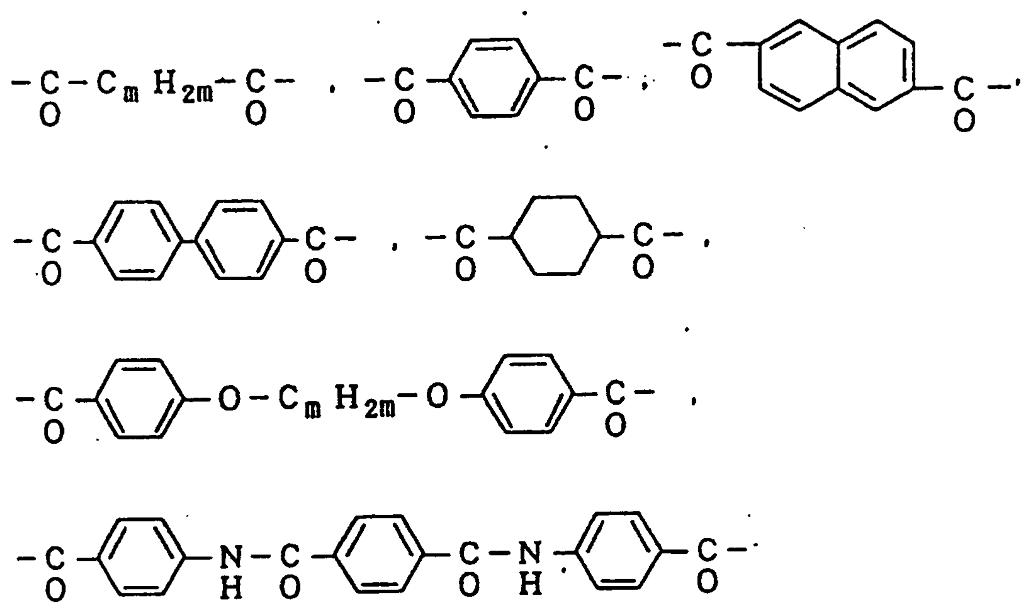
Q is the following:



etc.

wherein m is an integer of 2-16.

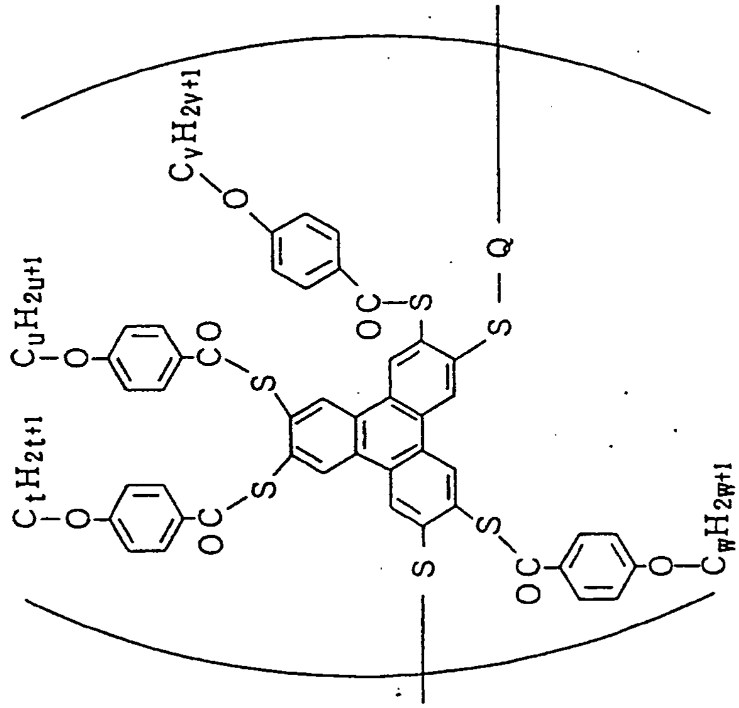
Preferable Q:

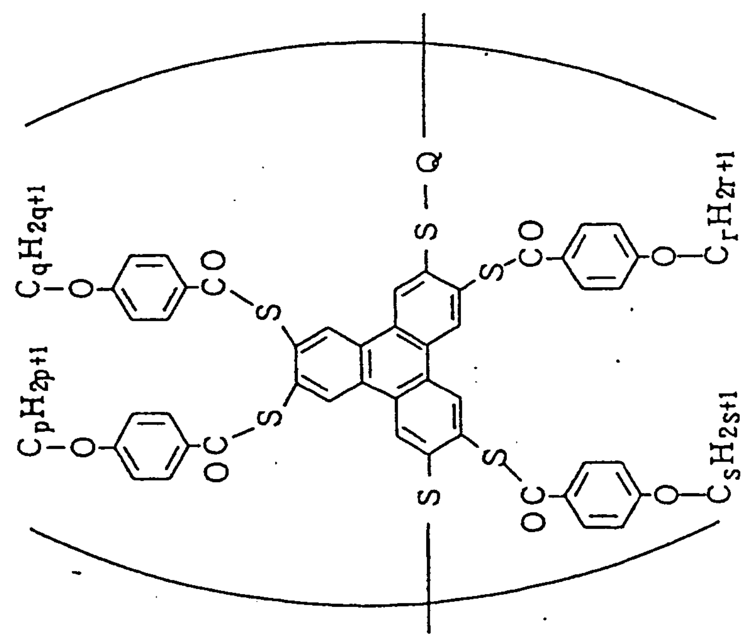


etc.

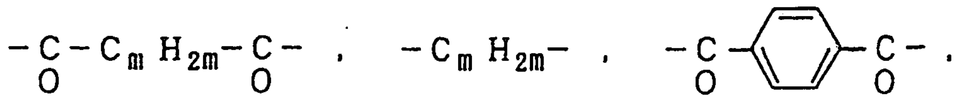
wherein m is an integer of 2-16, preferably 4-12.

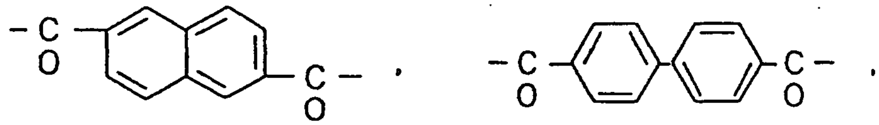
Polymer represented by the following:

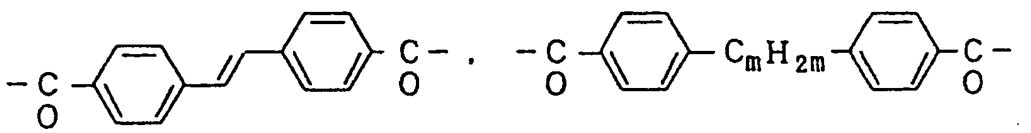


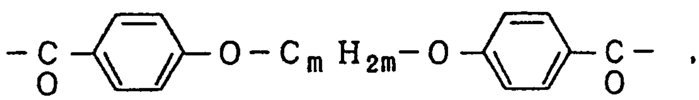


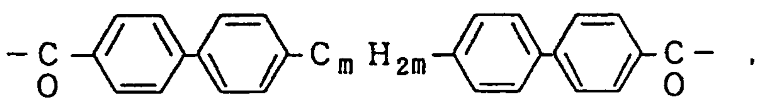
wherein p, q, r, s, t, u, v and w are each an integer of 1-18, preferably 3-14, and the average molecular weight is 5,000 - 100,000.
Q is the following:

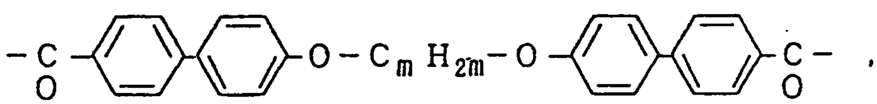


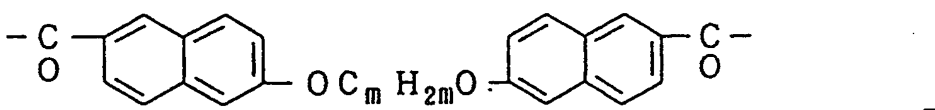


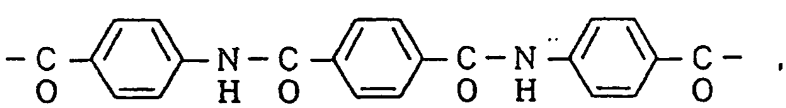


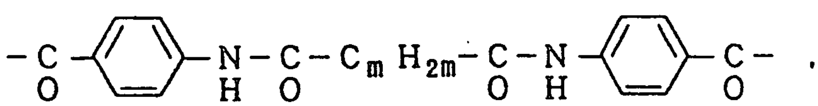


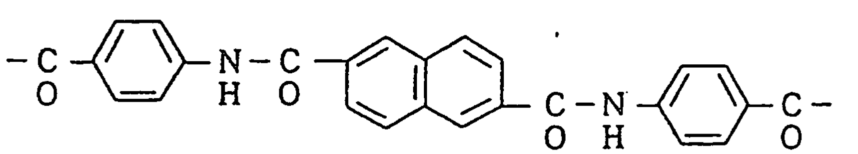








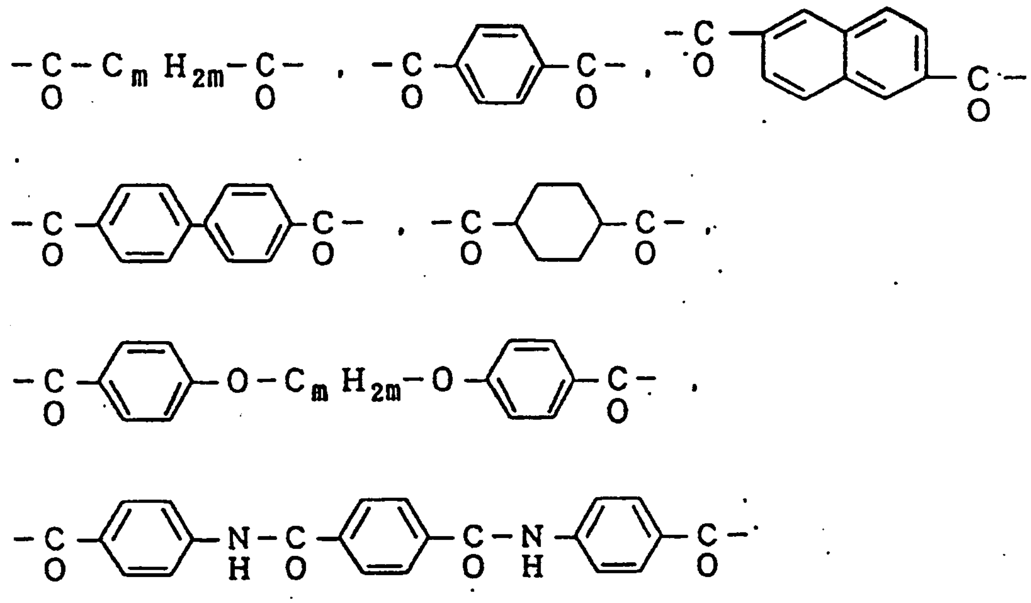




etc.

wherein m is an integer of 2-16.

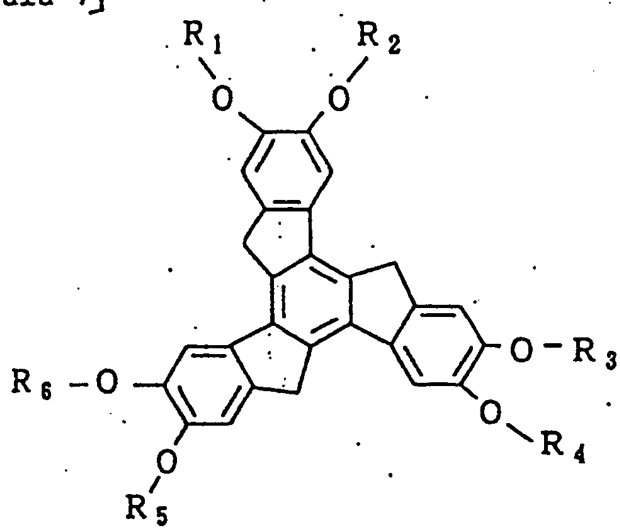
Preferable Q:



etc.

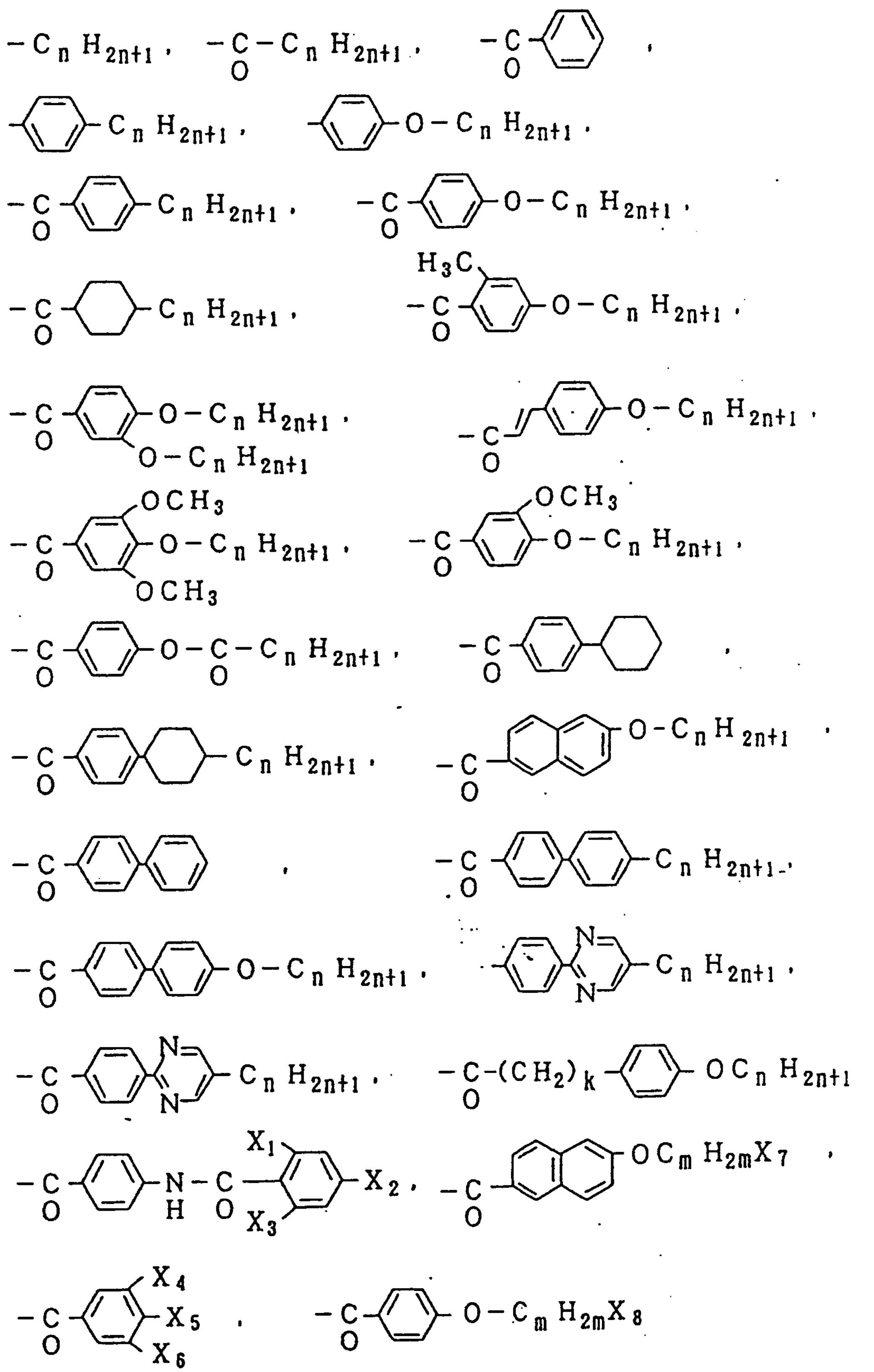
wherein m is an integer of 2-16, preferably 4-12.

[Structural formula 7]



wherein R_1-R_6 are each a monofunctional or bifunctional substituent group selected from the following groups:

Mono functional substituent groups:

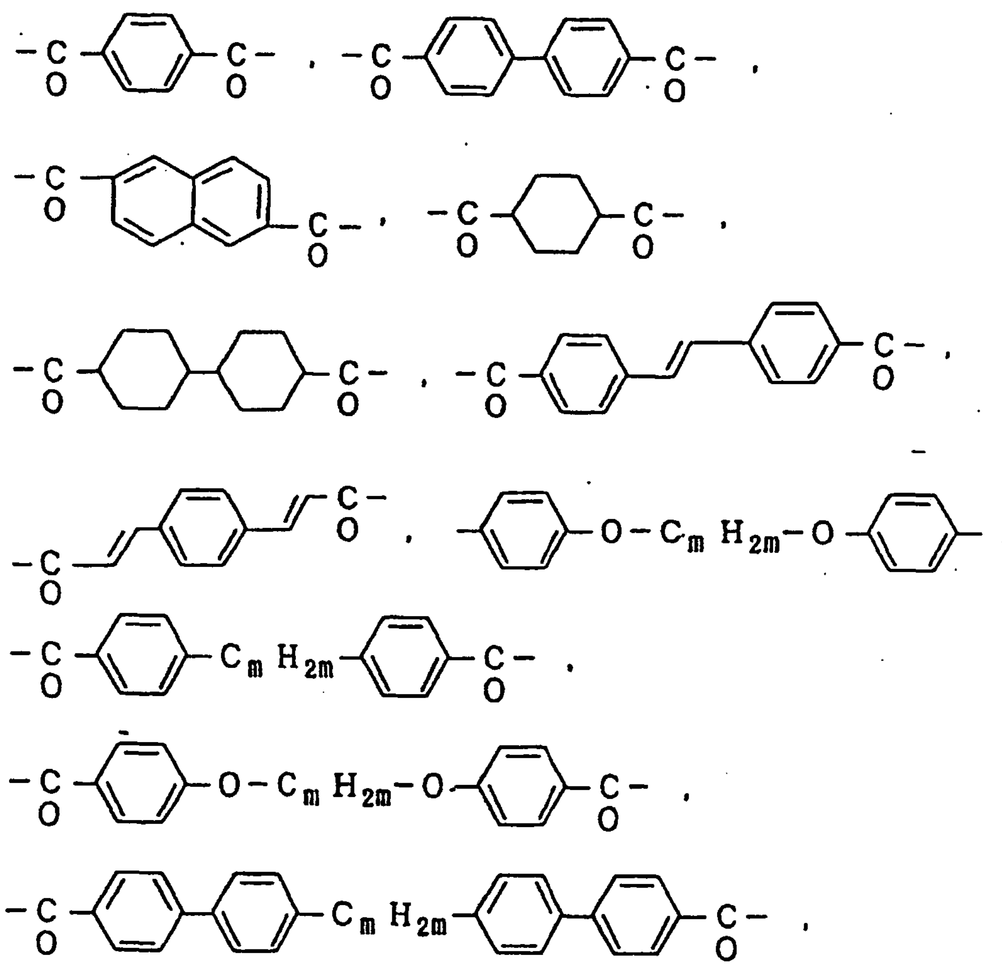


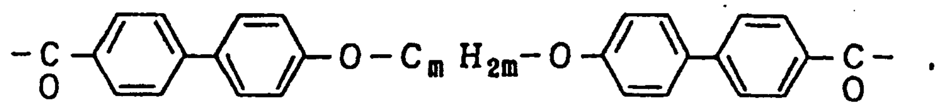
etc.

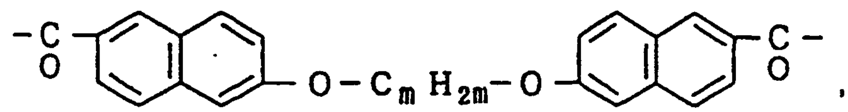
wherein C_nH_{2n+1} is a linear or branched alkyl group, n is an integer of 1-18, preferably 3-14, X_1-X_8 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl

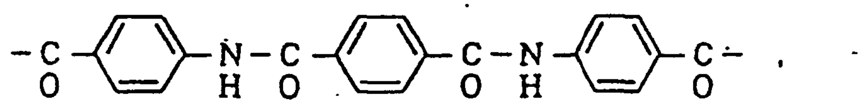
group, and ℓ is an integer of 1-18, preferably 1-10, C_mH_{2m} is a linear or branched alkylene chain, and m is an integer of 1-16, preferably 2-10.
Bifunctional substituent groups:

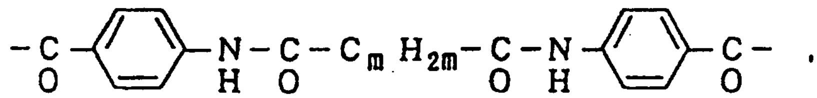
$-C_mH_{2m}-$, $-\underset{O}{C}-C_mH_{2m}-\underset{O}{C}-$,

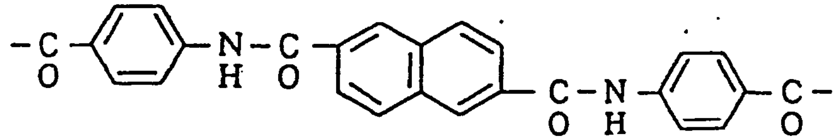








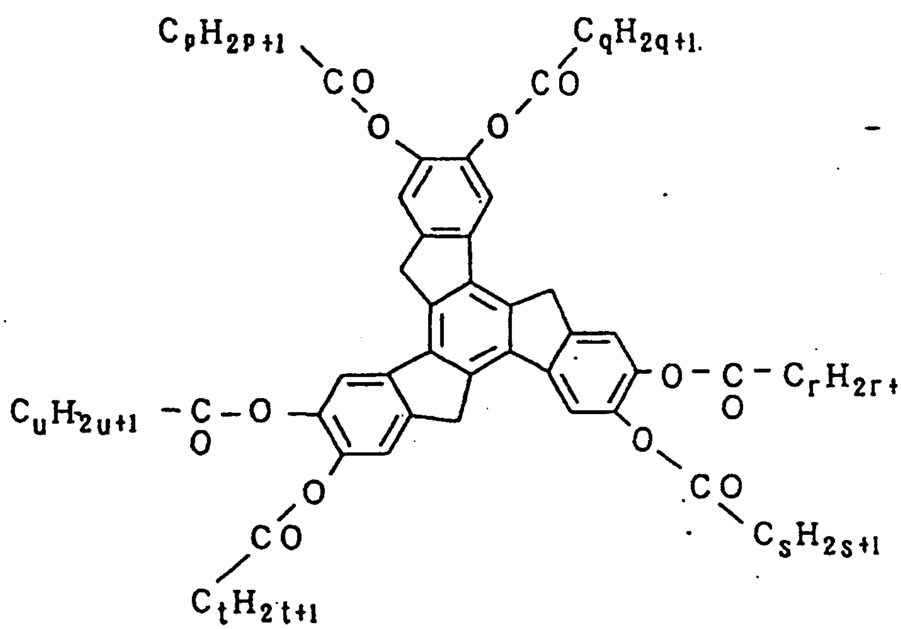




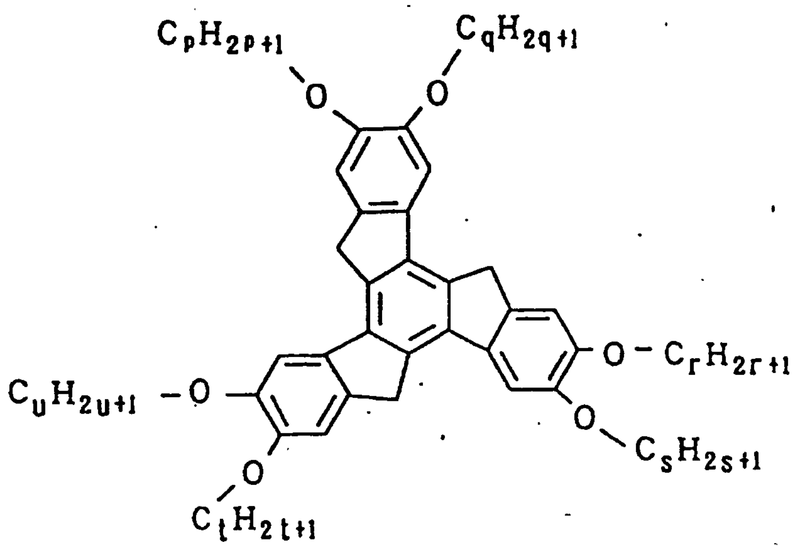
etc.

wherein C_mH_{2m} is a linear or branched alkylene chain, and m is an integer of 2-16, preferably 4-12.

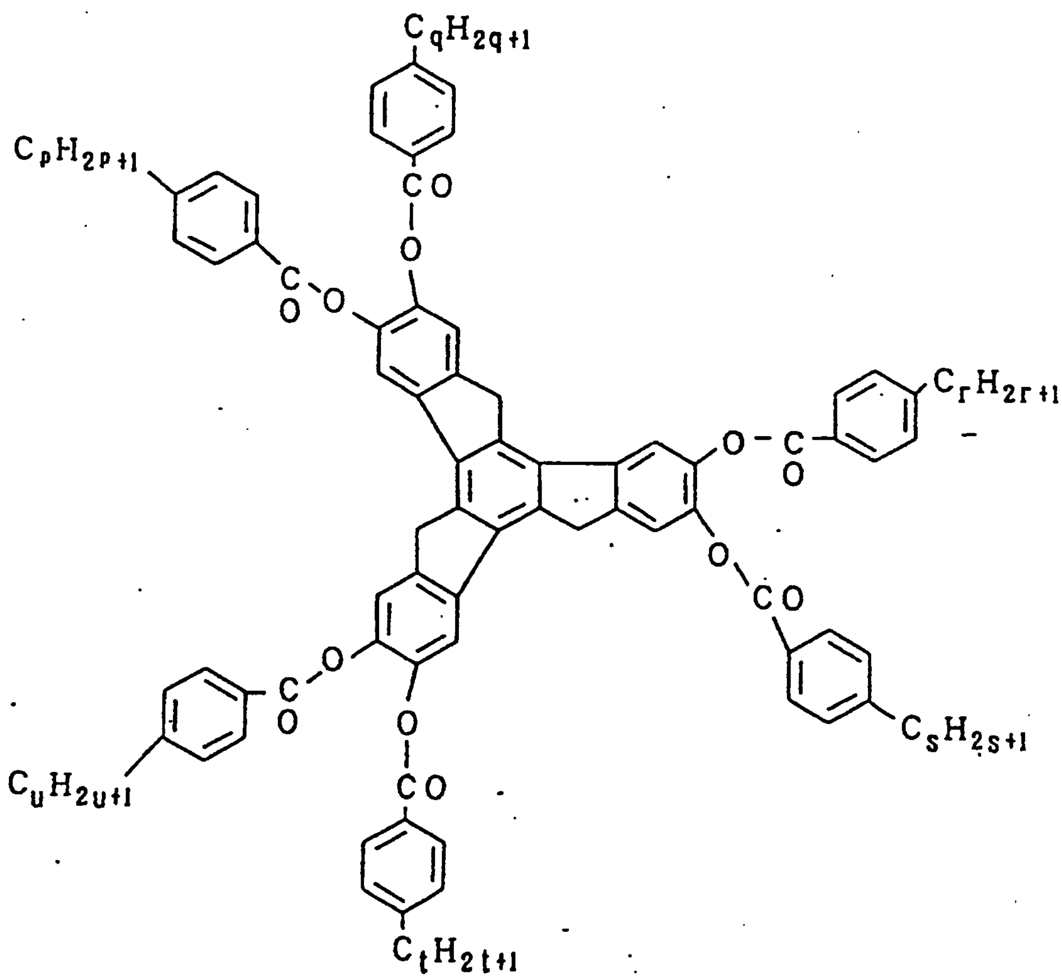
Examples of the concrete structures:



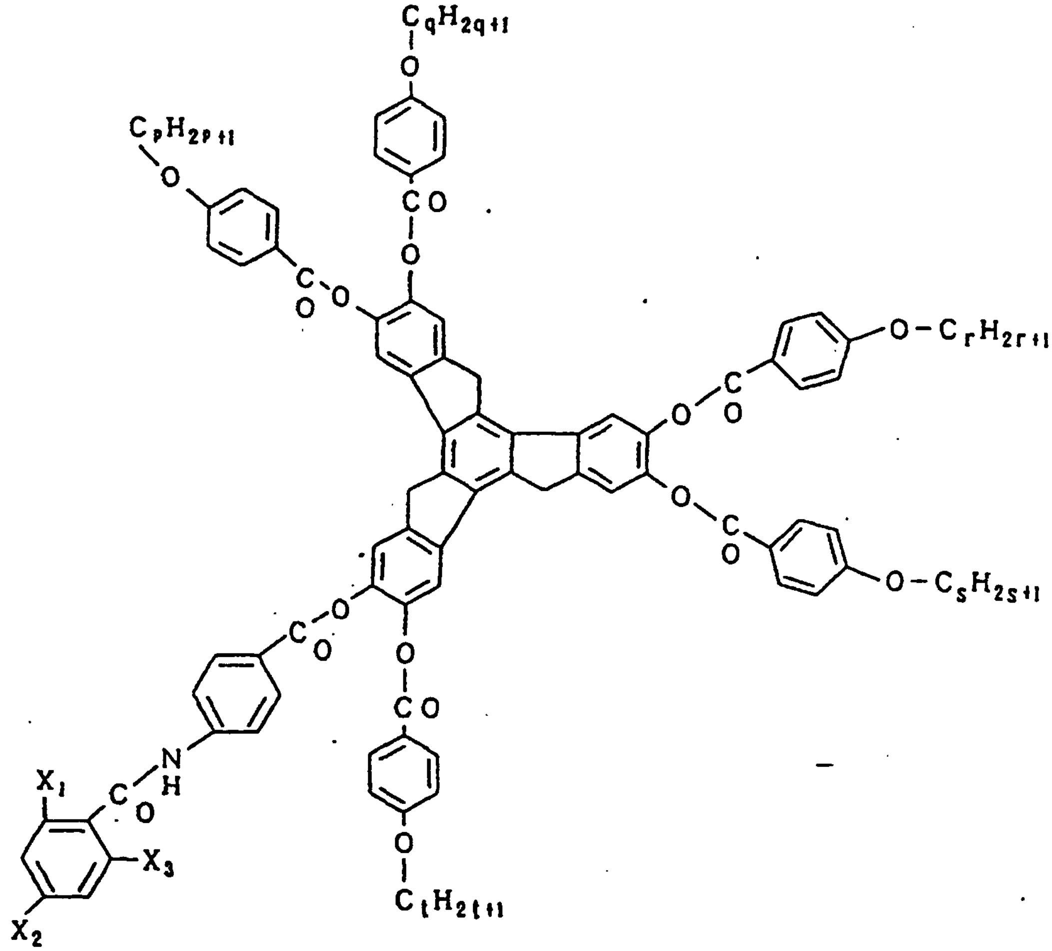
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



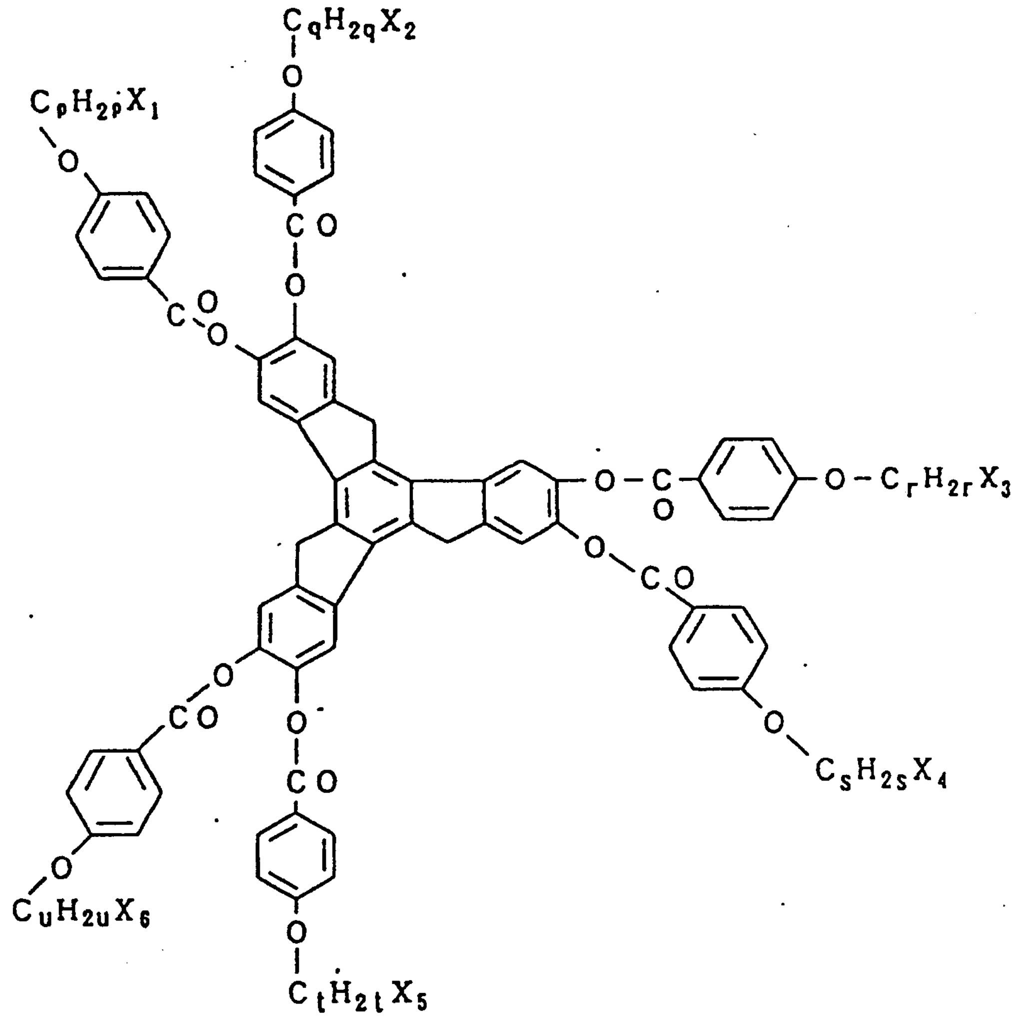
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



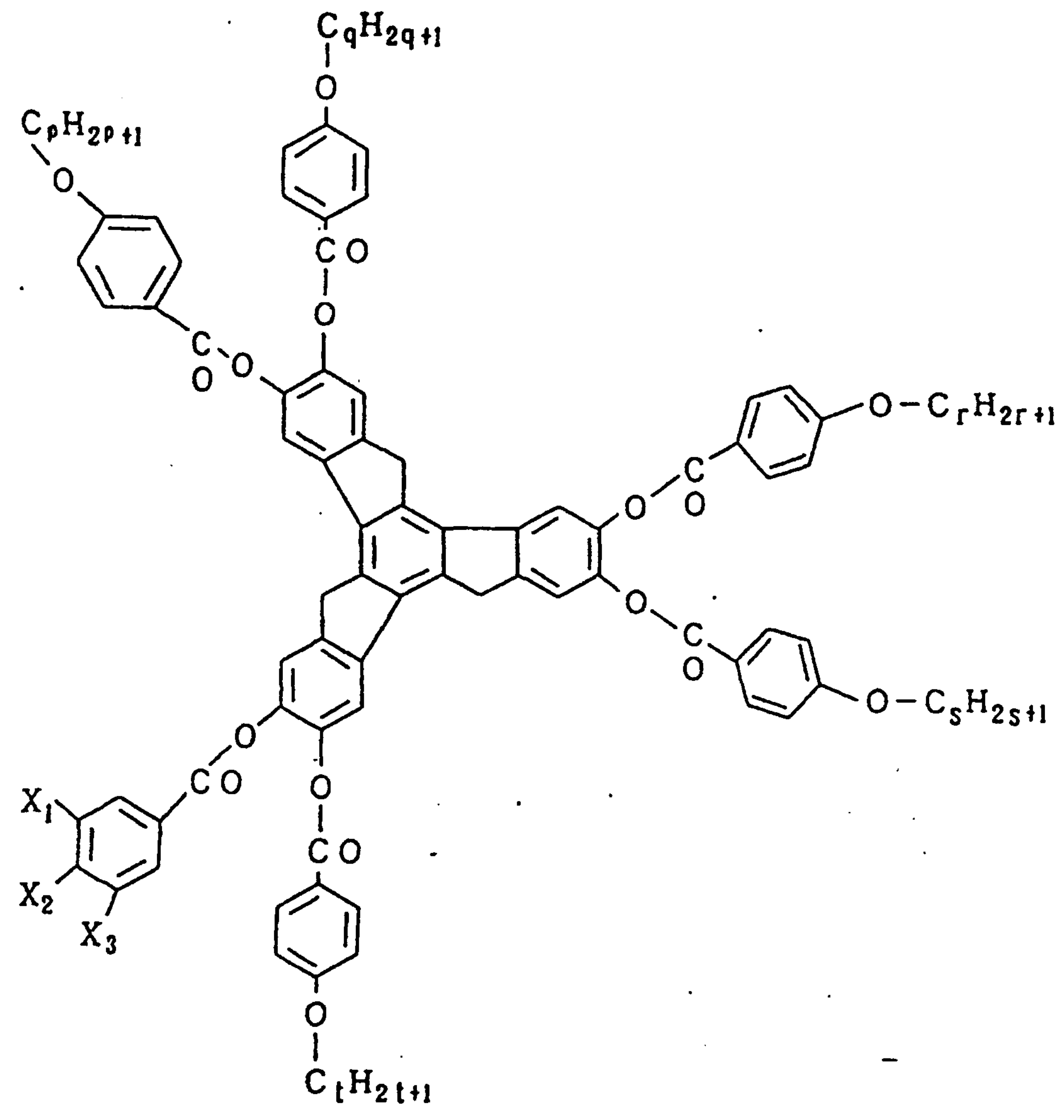
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



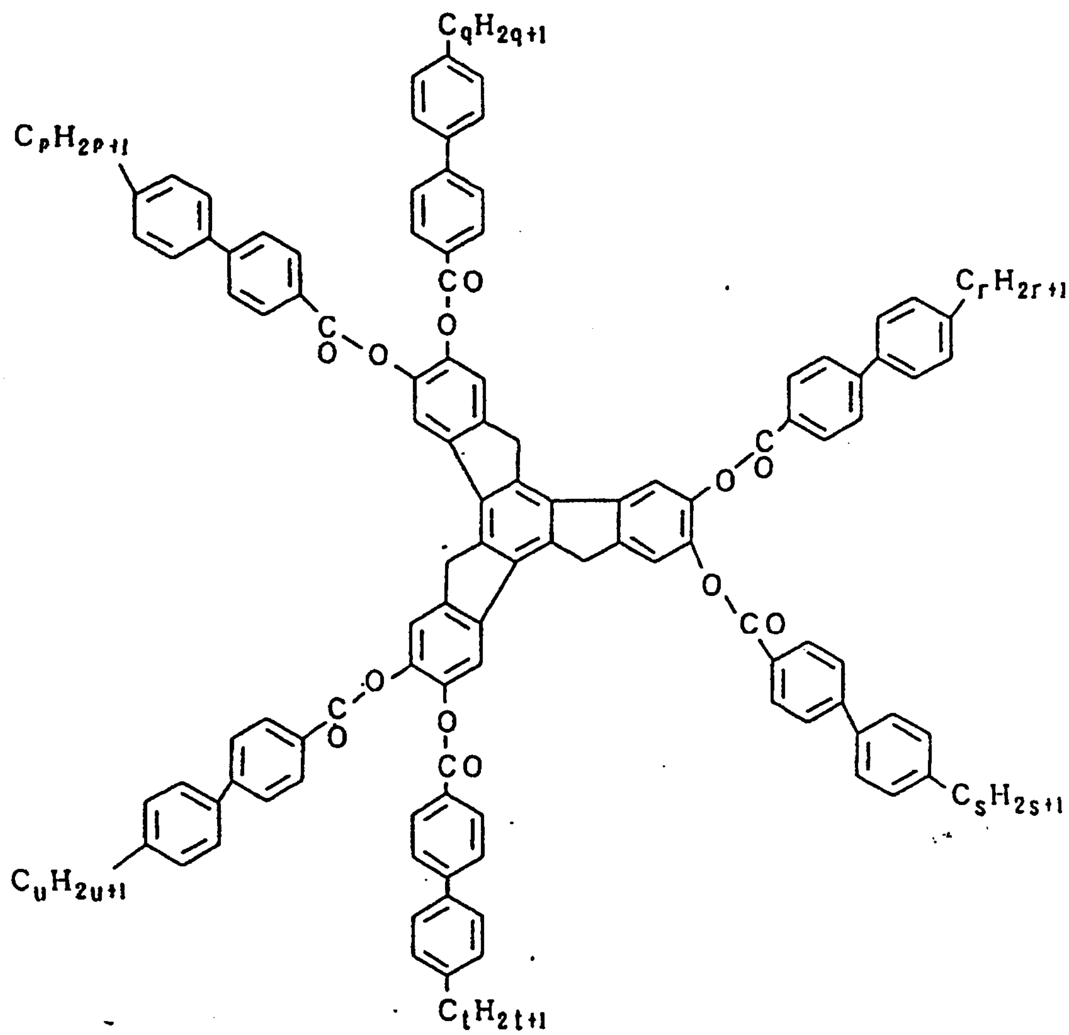
wherein p, q, r, s and t are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14, X_1-X_6 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

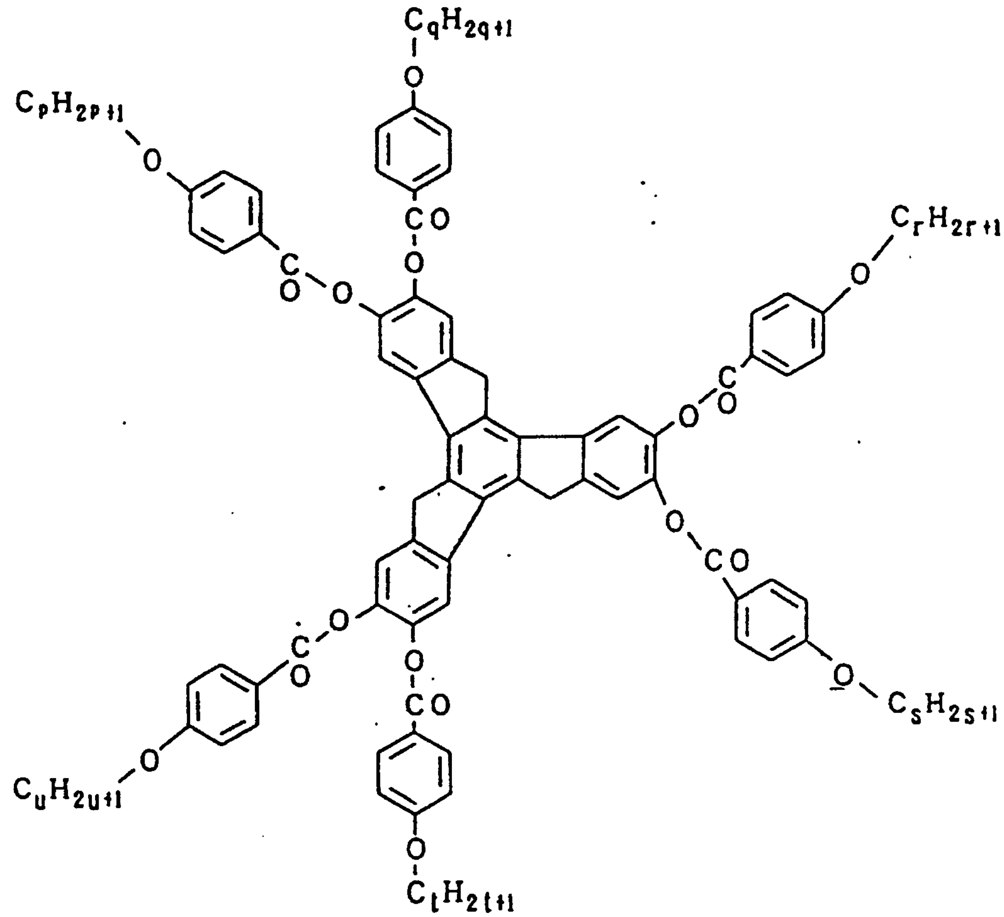


wherein p, q, r, s and t are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

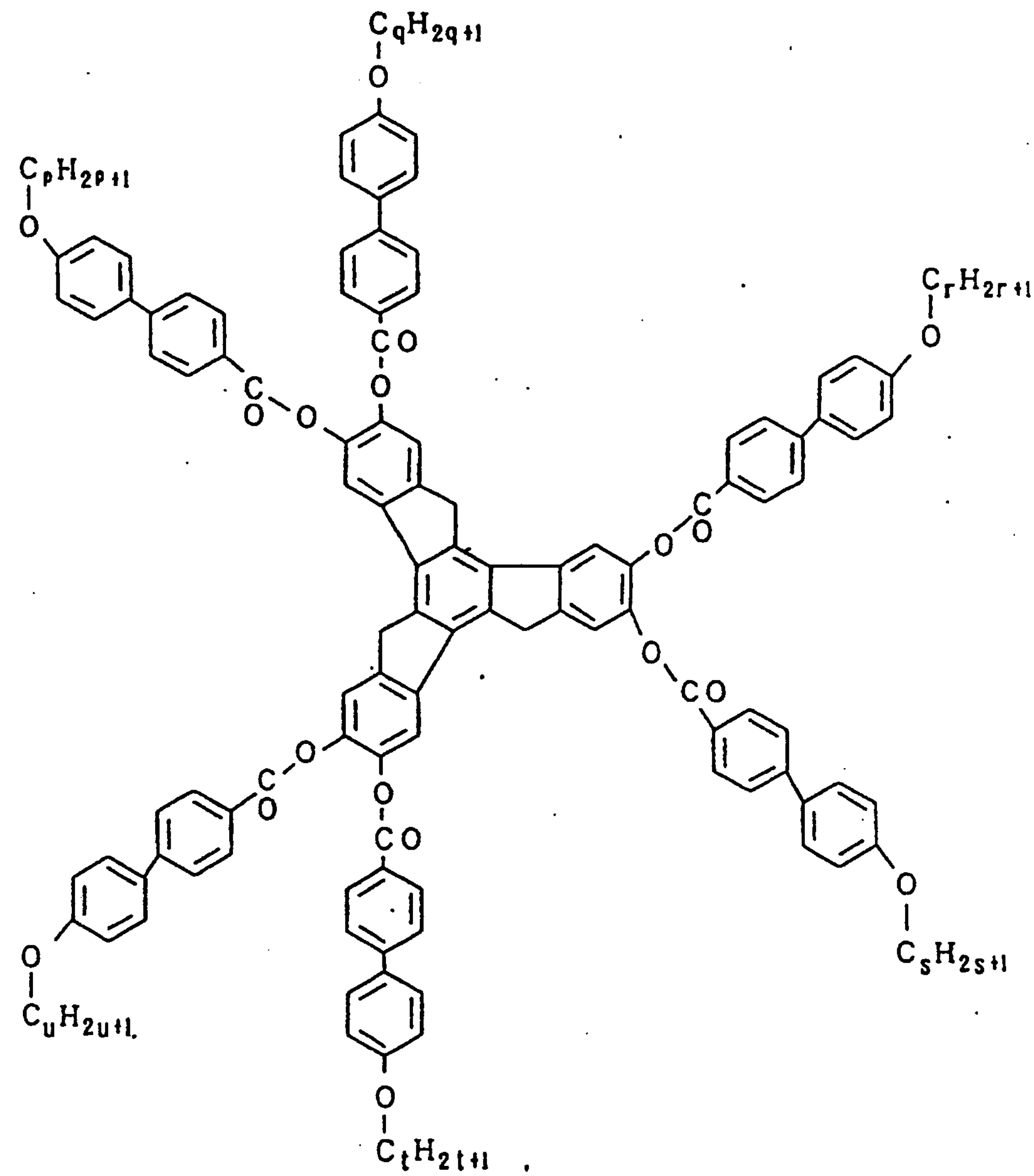


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

10

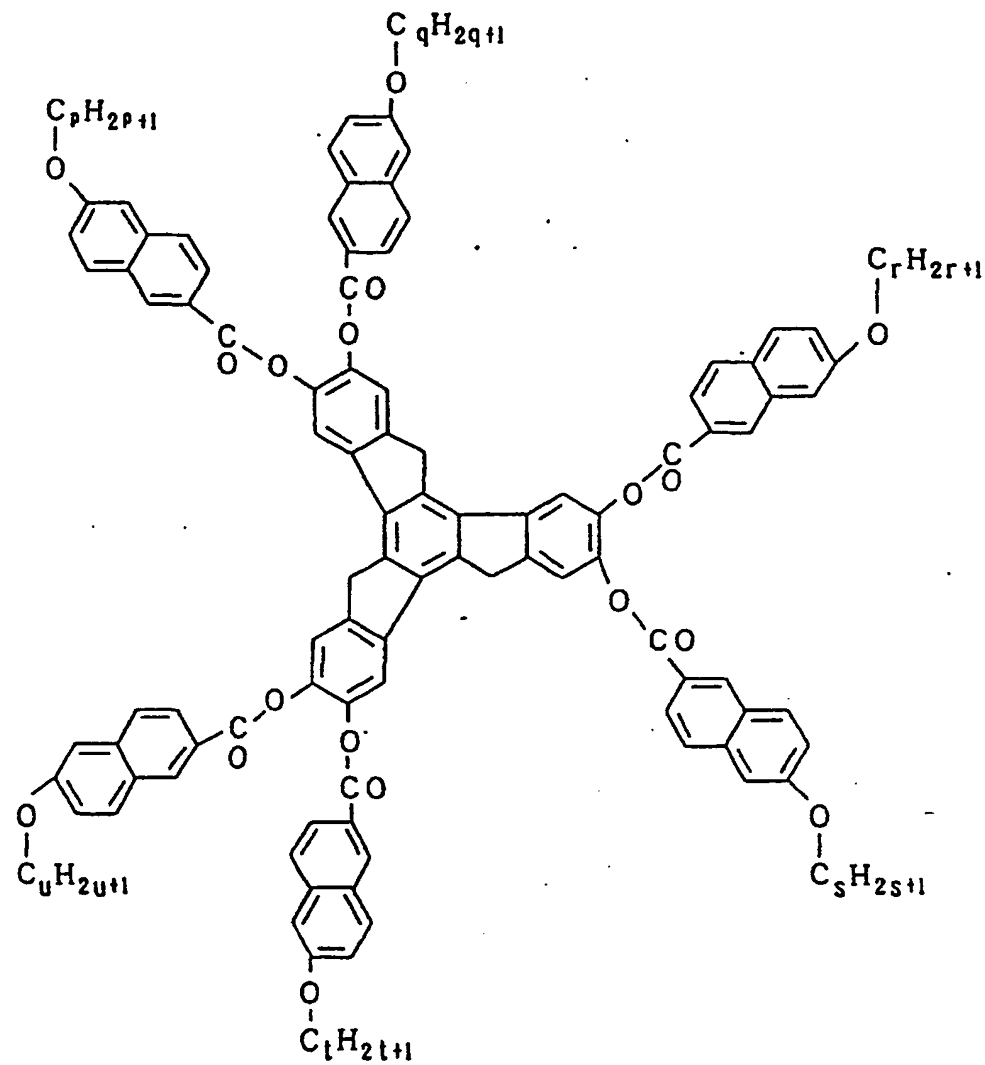


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



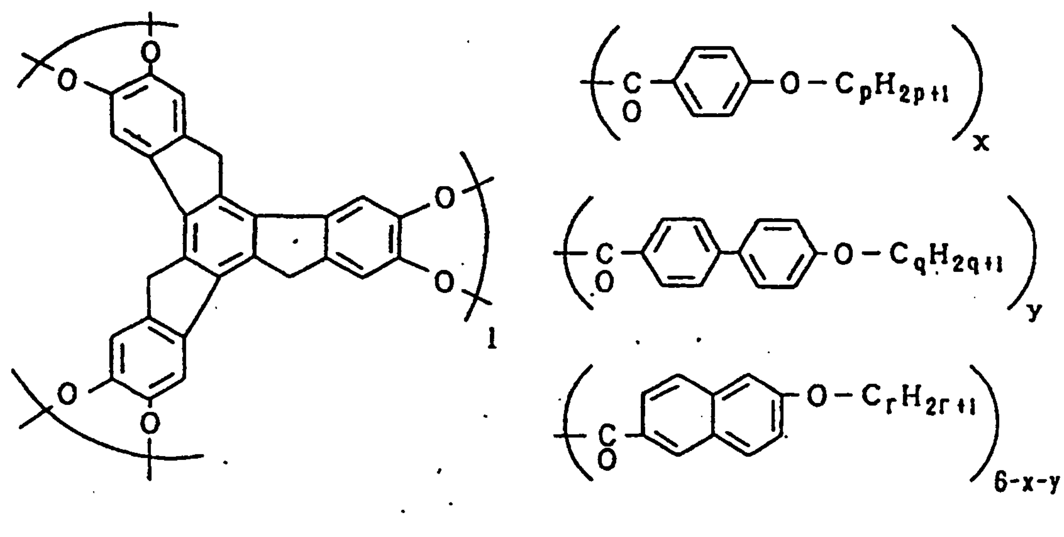
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

Ic



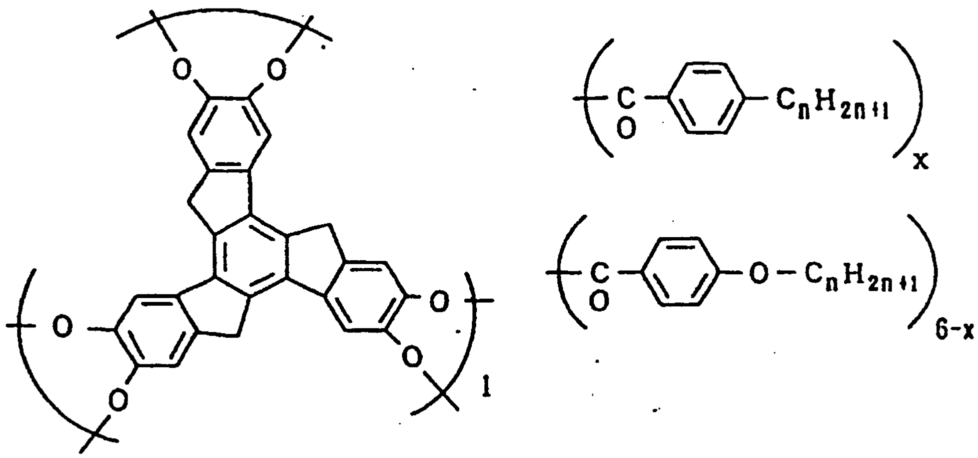
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

Composition of the following:



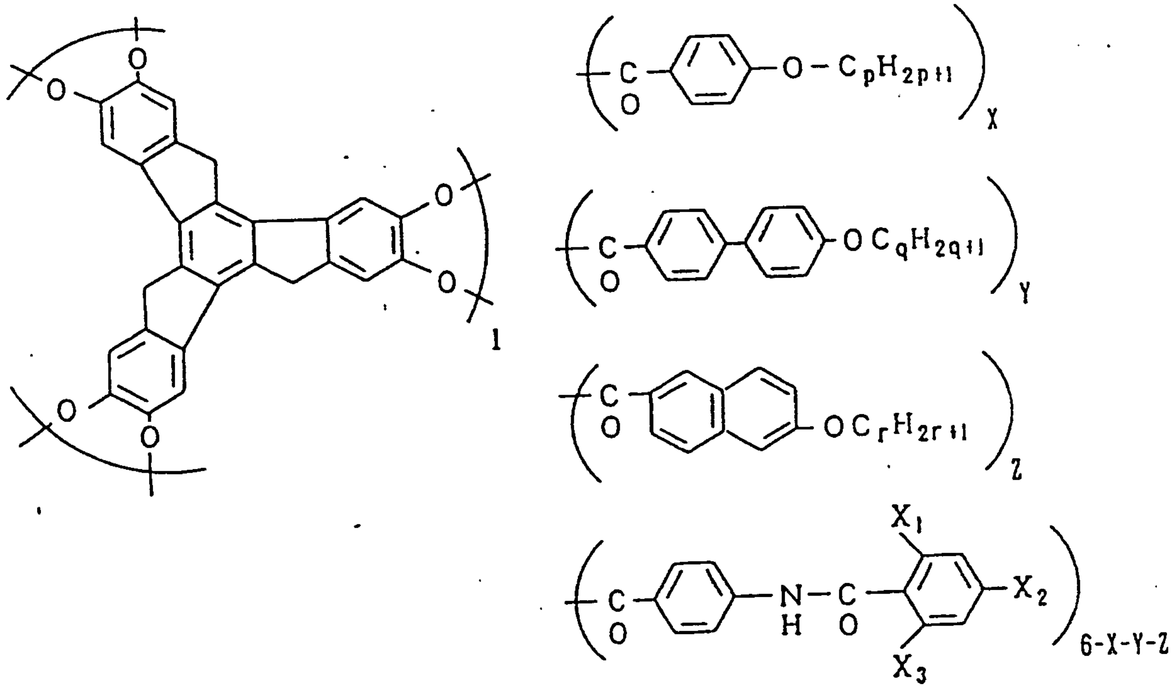
wherein 0≦x≦6, 0≦y≦6 in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14.

Composition of the following:



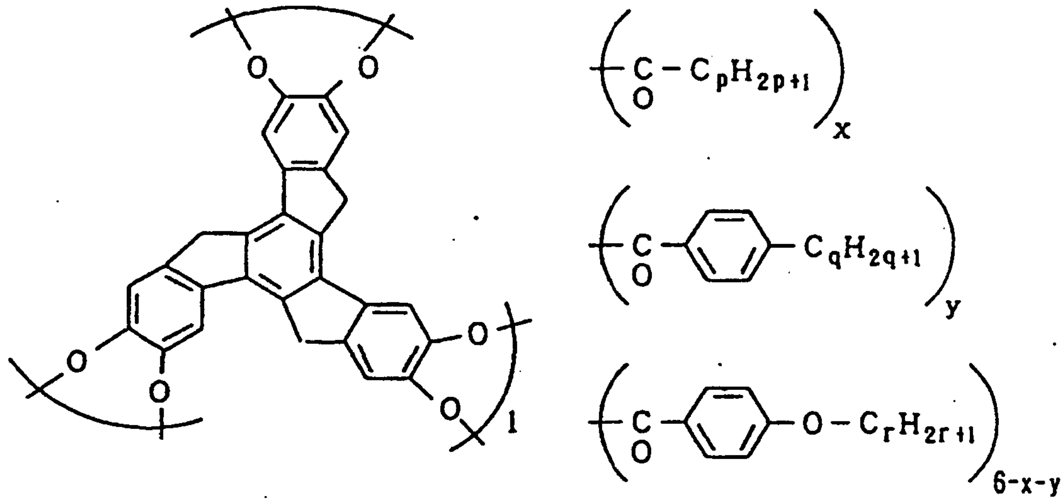
wherein 0≦x≦6 in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14.

Composition of the following:

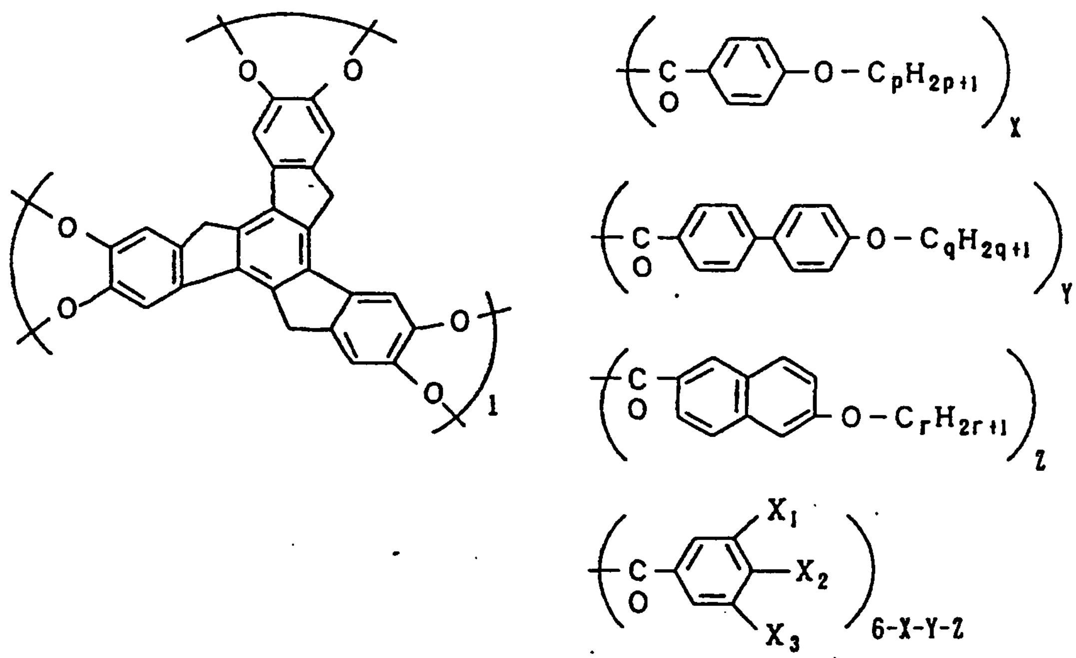


wherein 0≦x≦6, 0≦y≦6, 0≦z≦6 in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

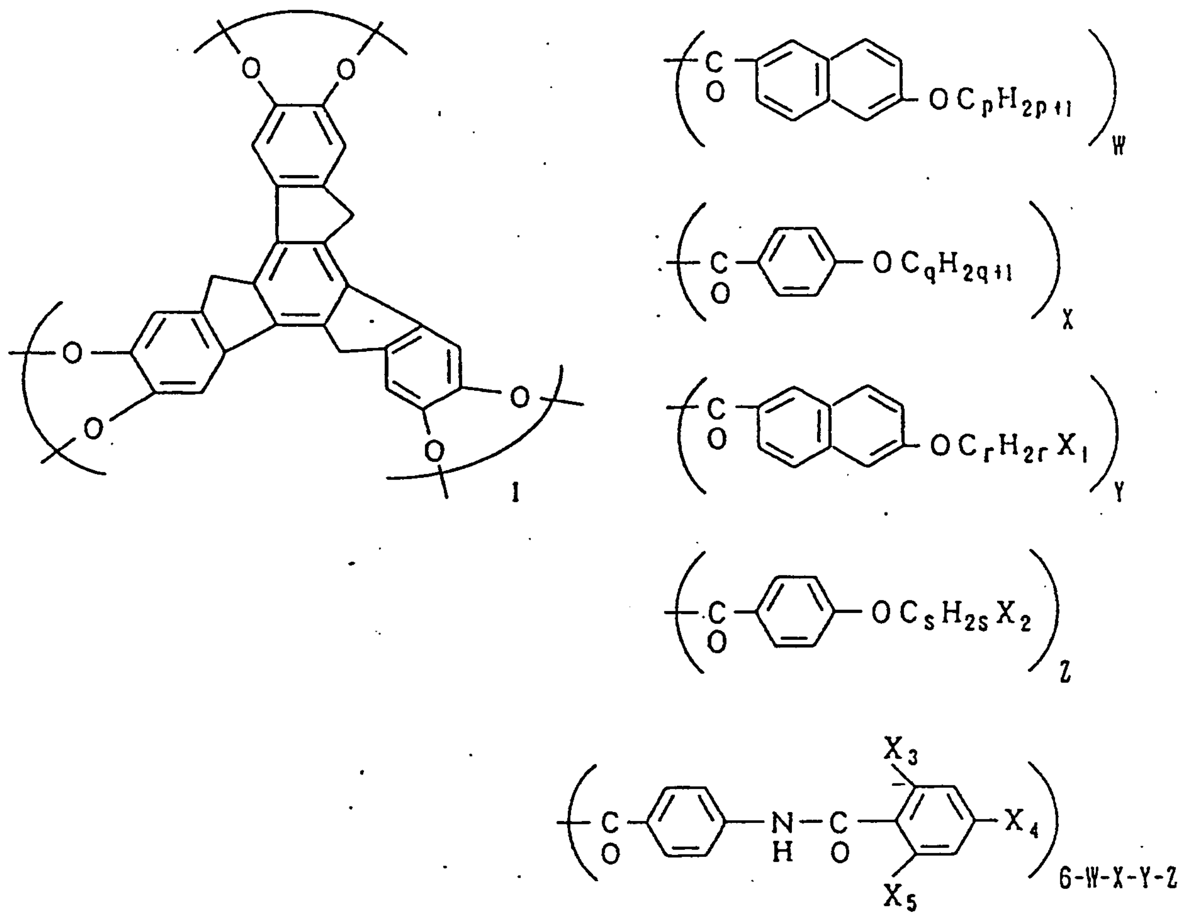
Composition of the following:



wherein 0≦x≦6, 0≦y≦6 in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14.
Composition of the following:

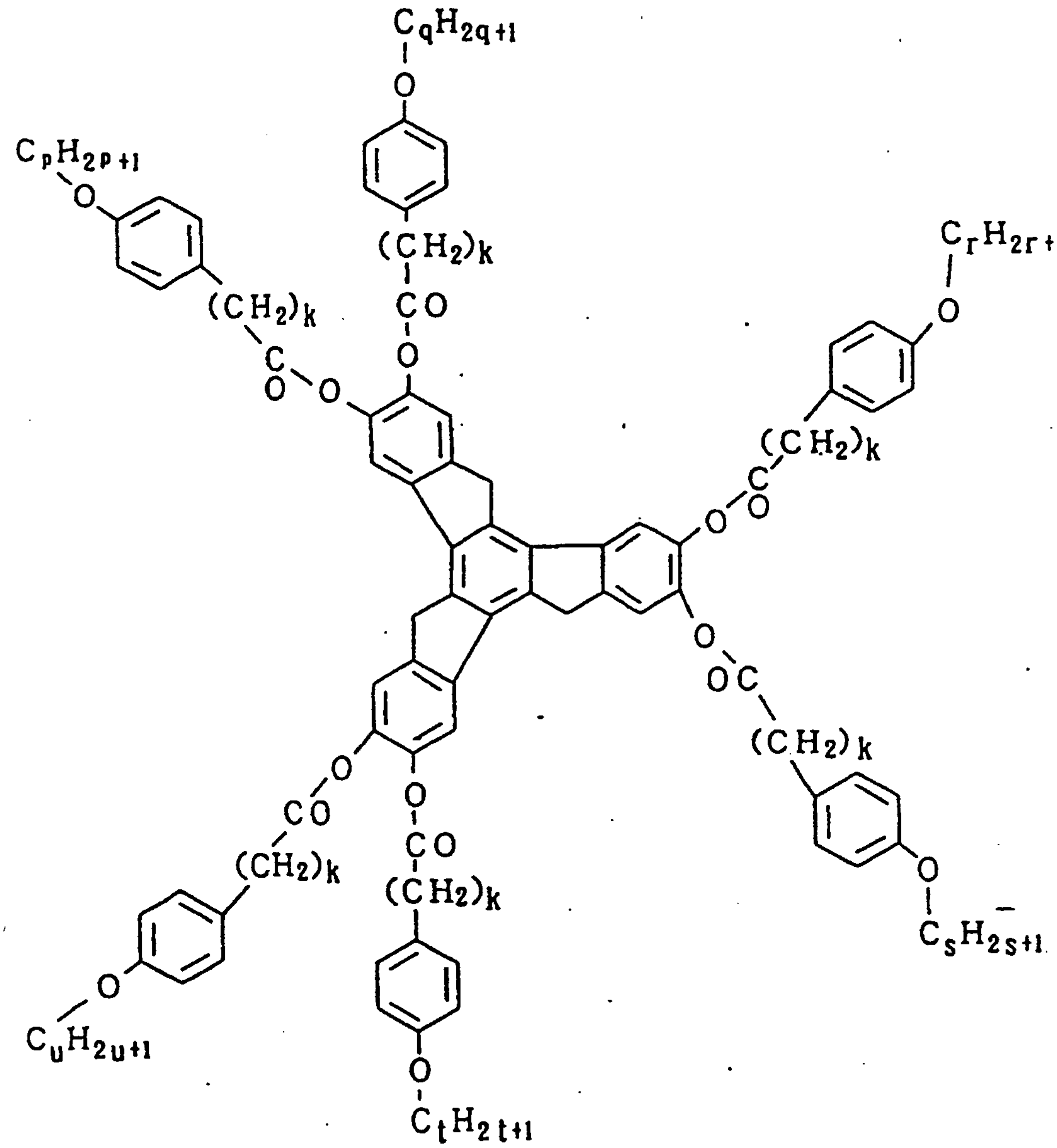


wherein 0≦x≦6, 0≦y≦6, 0≦z≦6 in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14, p, q and r are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently, H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.
Composition of the following:

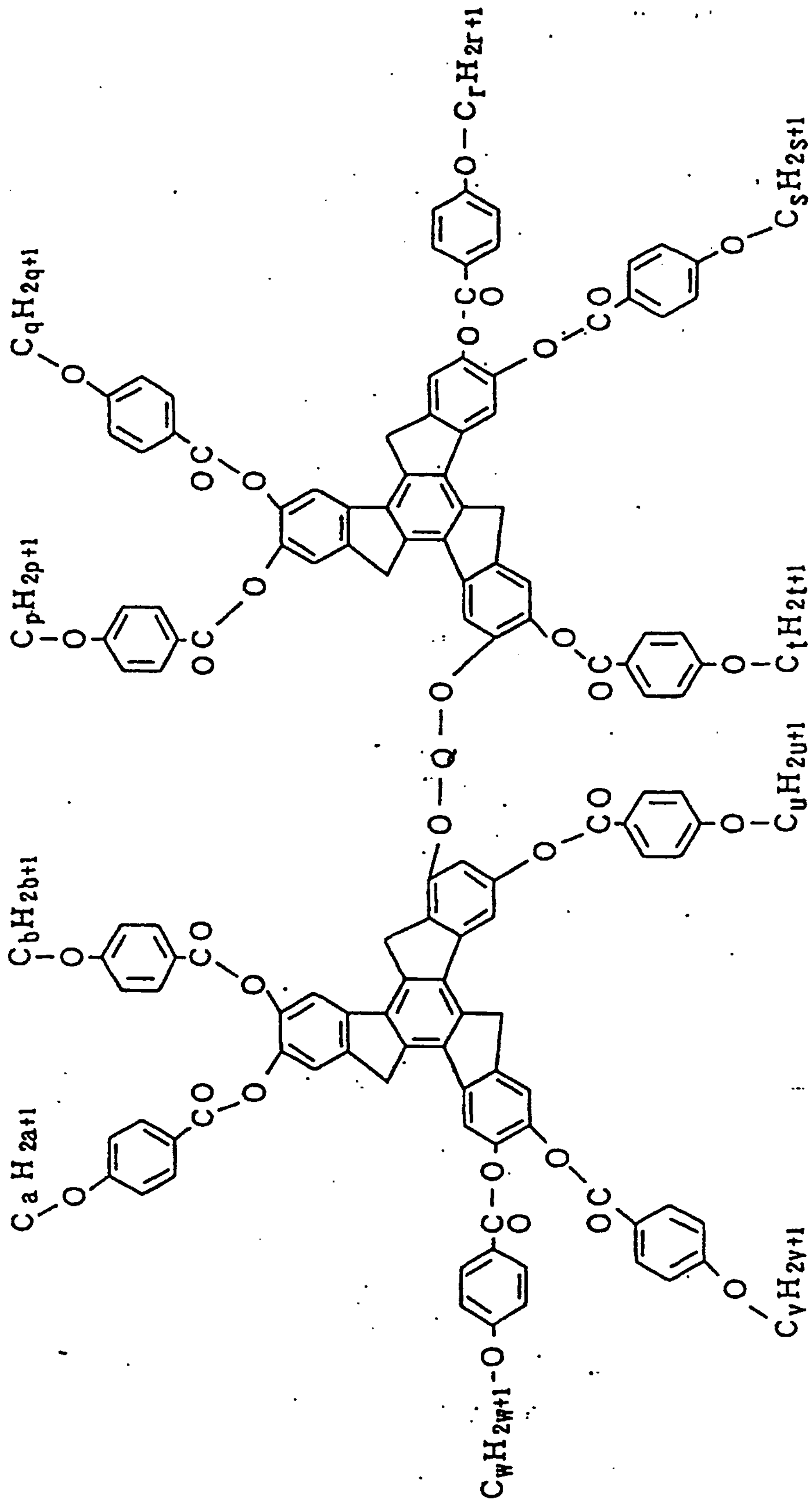


wherein $0 \leqq x \leqq 6$, $0 \leqq y \leqq 6$, $0 \leqq z \leqq 6$ in the molar ratio, p, q, r and s are each an integer of 1-18, preferably 3-14, X_1-X_5 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

/0:

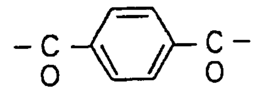


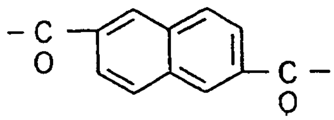
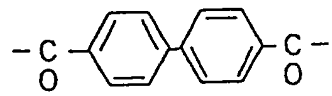
wherein p, q, r, s, t, u, v and w are each an integer of 3-18, preferably 5-14, k is 1, 2 or 3.

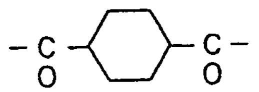
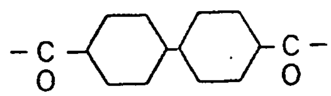


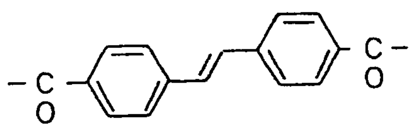
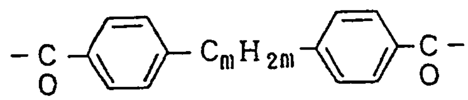
wherein p, q, r, s, t, u, v, w, a and b are each an integer of 1-18, preferably 3-14.

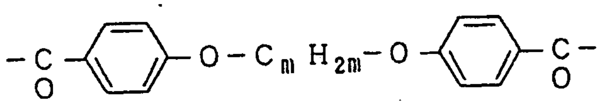
Q is the following:

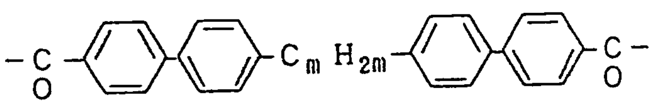
$-\underset{O}{C}-C_mH_{2m}-\underset{O}{C}-$, $-C_mH_{2m}-$,  ,

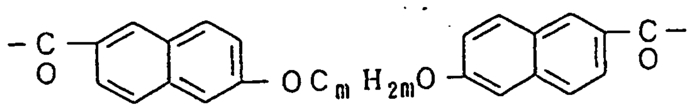
 ,  ,

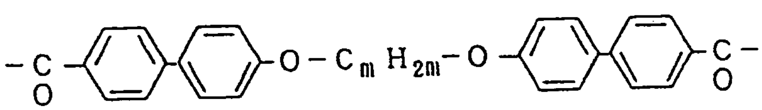
 ,  ,

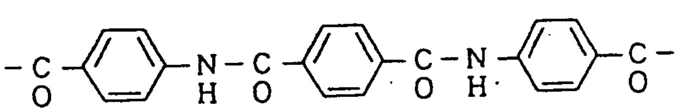
 ,  ,

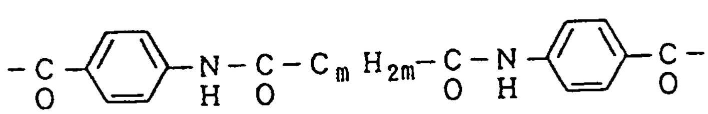
 ,

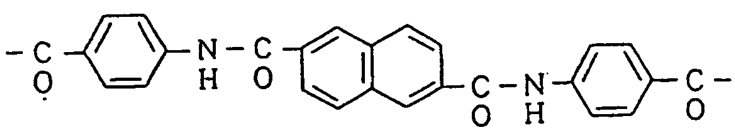
 ,

 ,

 ,

 ,

 ,

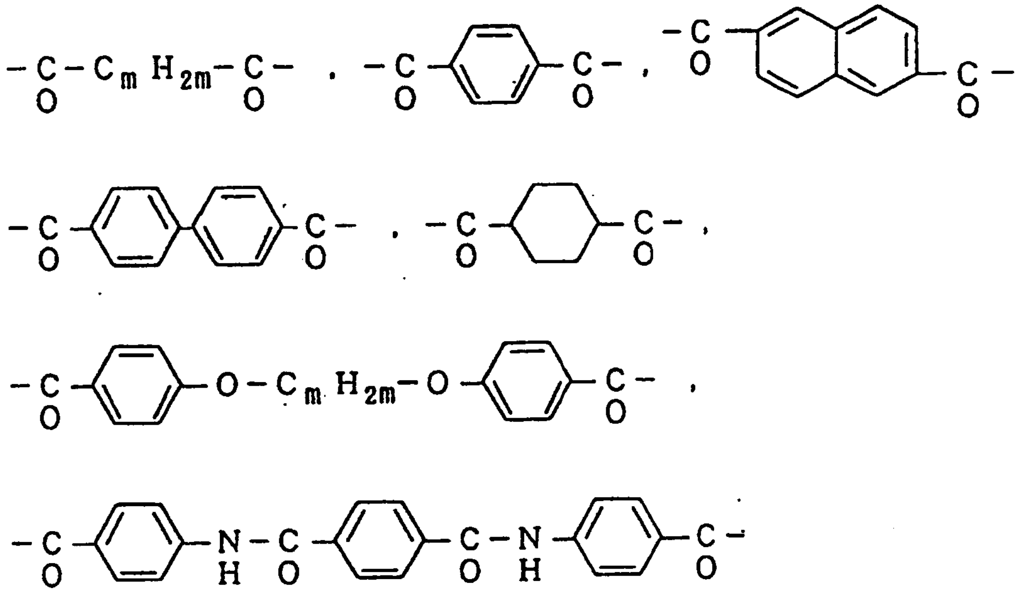


etc.

wherein m is an integer of 2-16.

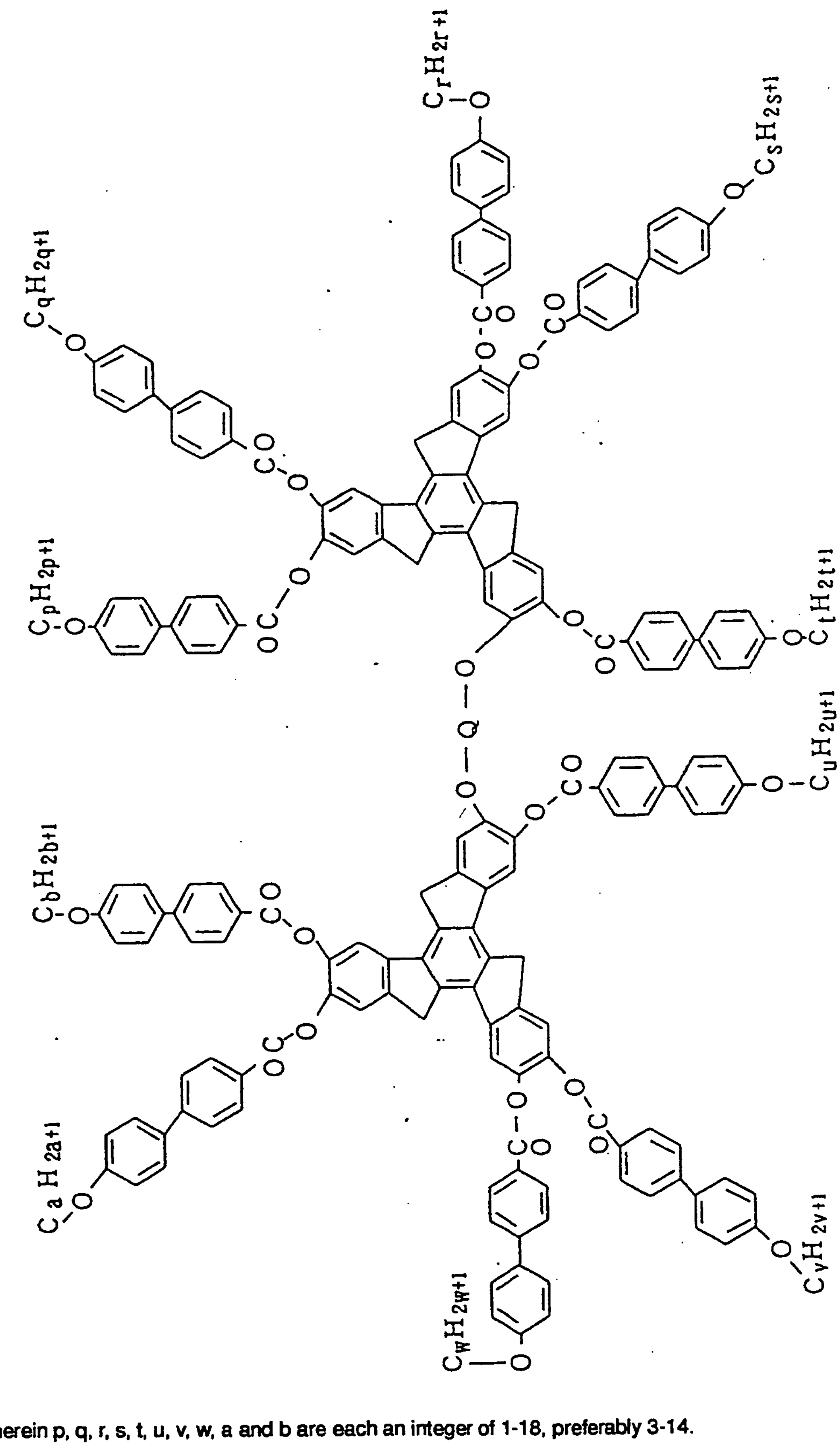
Preferable Q:

110

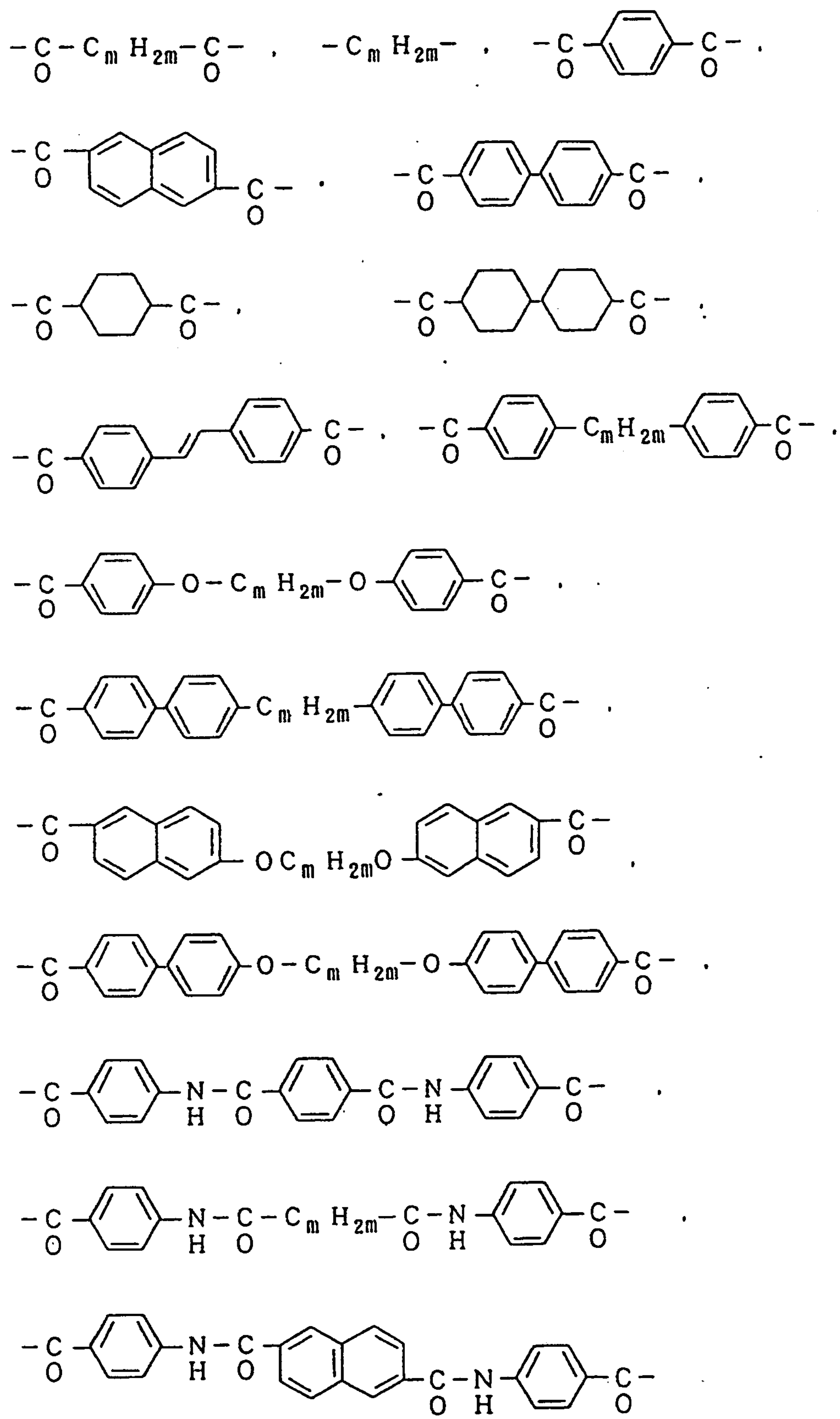


etc.

wherein m is an integer of 2-16, preferably 4-12.



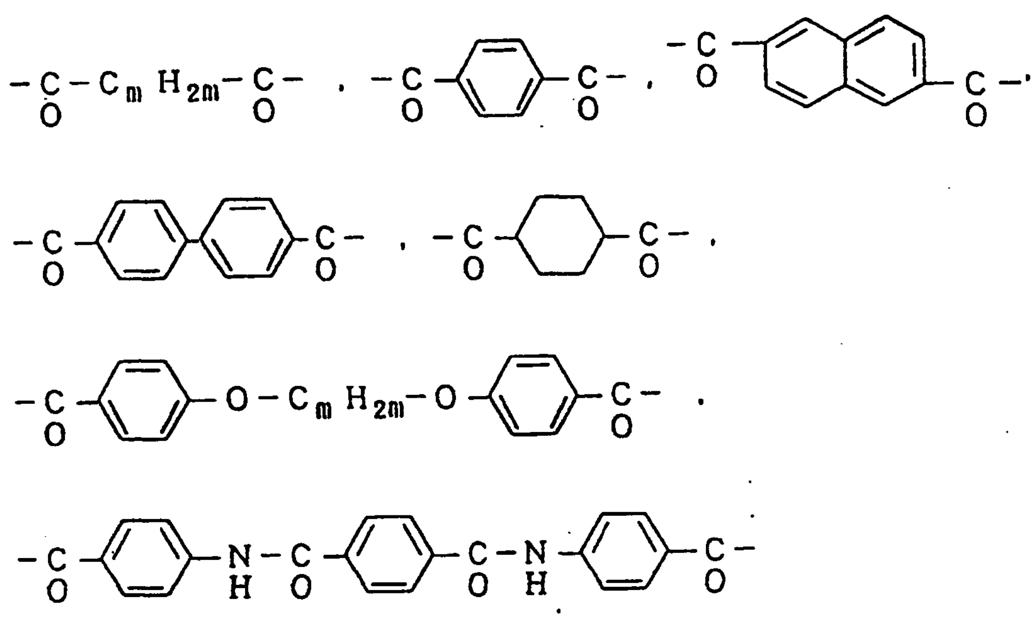
wherein p, q, r, s, t, u, v, w, a and b are each an integer of 1-18, preferably 3-14.
Q is the following:



etc.

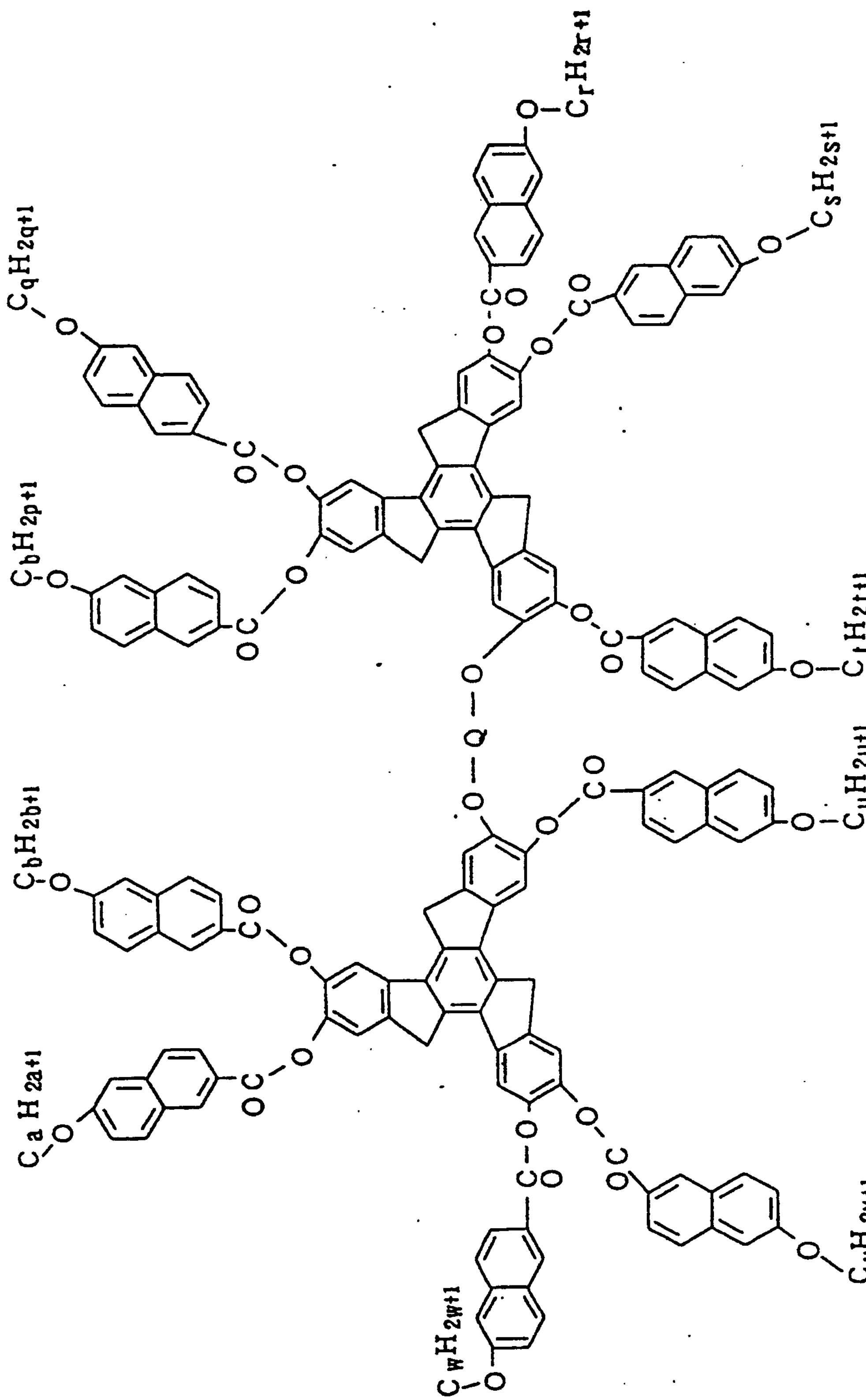
wherein m is an integer of 2-16.

Preferable Q:

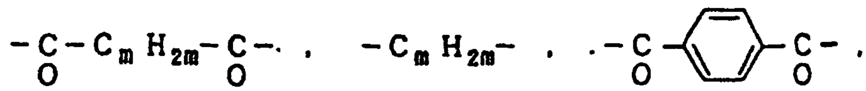


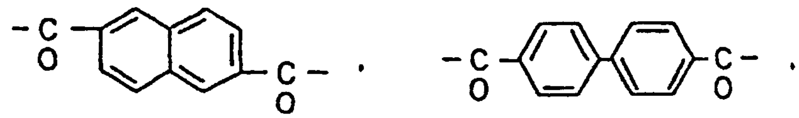
etc.

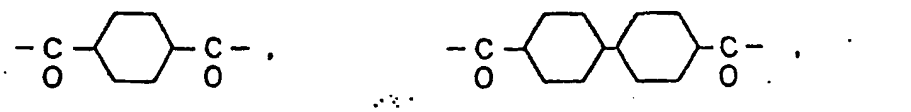
wherein m is an integer of 2-16, preferably 4-12.

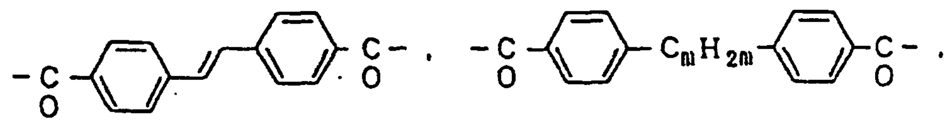


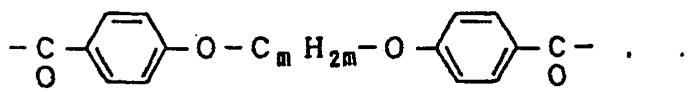
wherein p, q, r, s, t, u, v, w, a and b are each an integer of 1-18, preferably 3-14.
Q is the following:

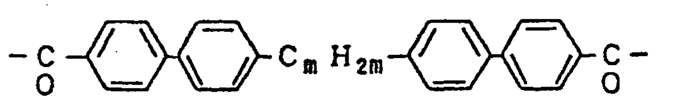


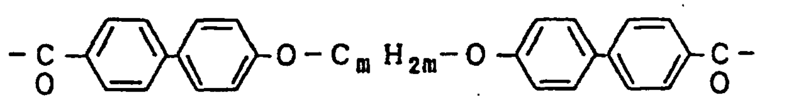


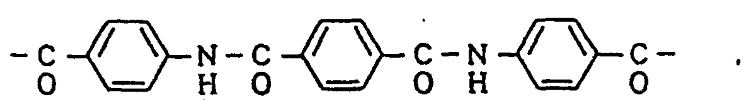


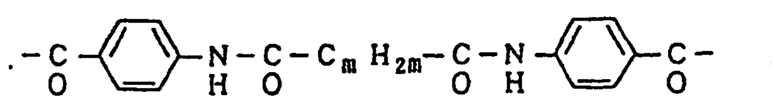


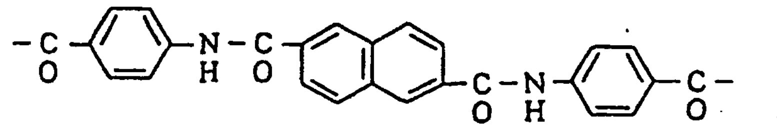








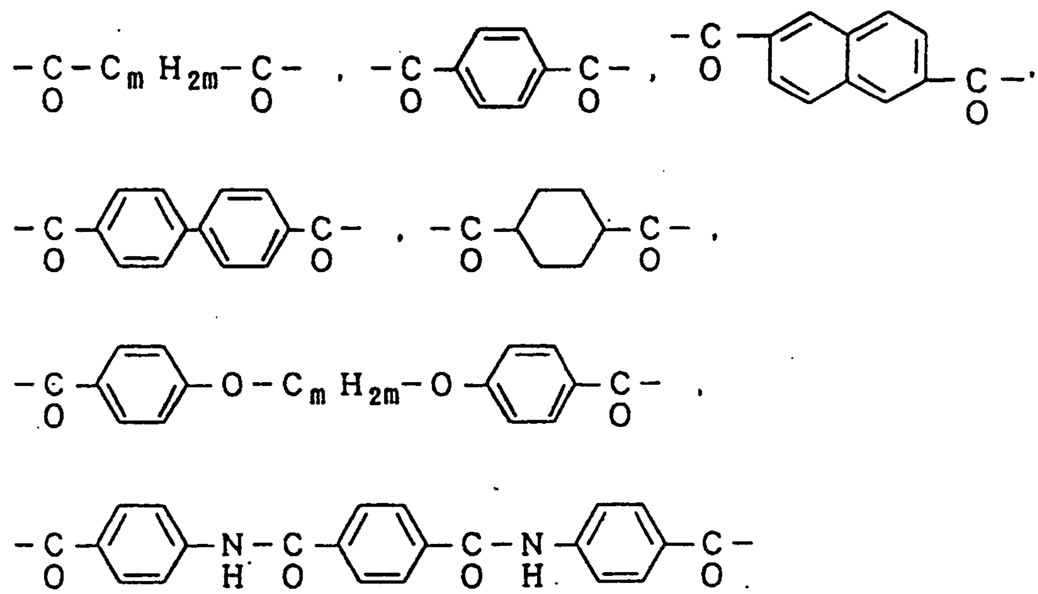




etc.

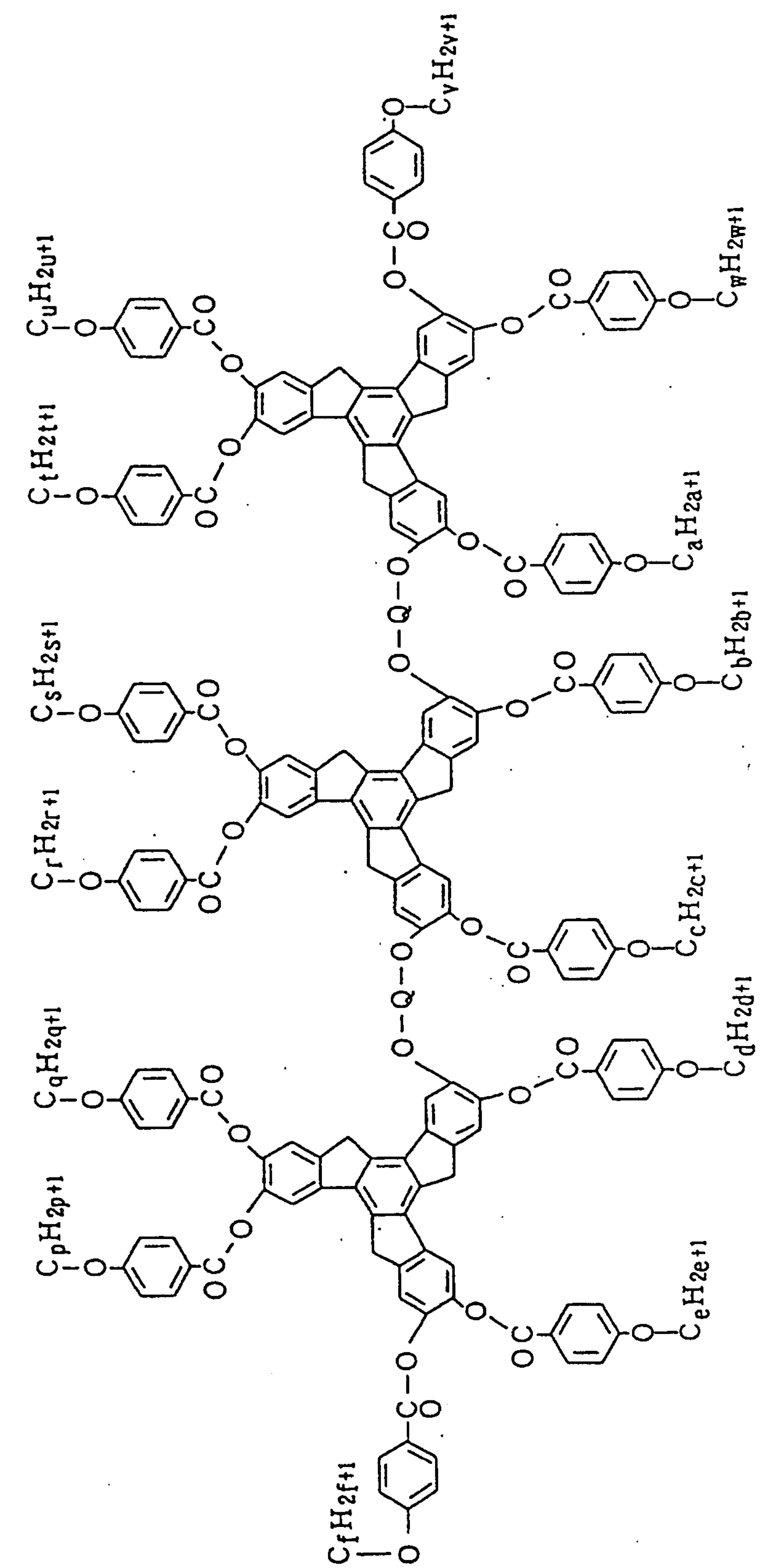
wherein m is an integer of 2-16.

Preferable Q:



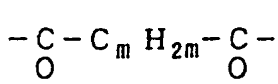
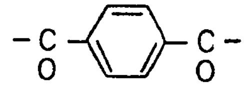
etc.

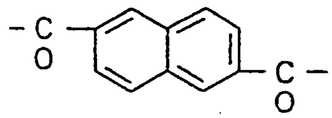
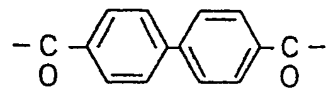
wherein m is an integer of 2-16, preferably 4-12.

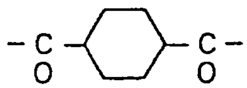
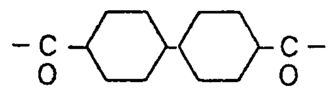


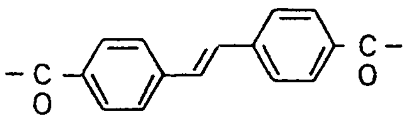
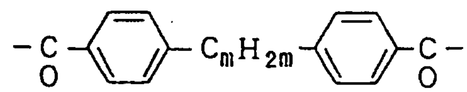
wherein p, q, r, s, t, u, v, w, a, b, c, d, e and f are each an integer of 1-18, preferably 3-14.

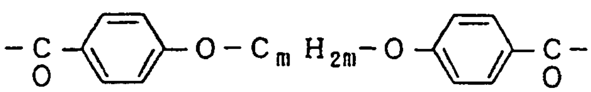
Q is the following:

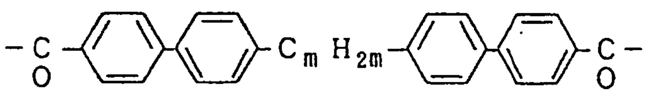
, ,

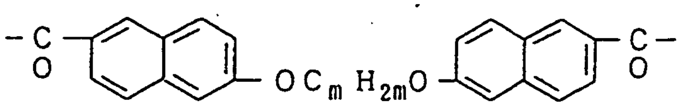
, ,

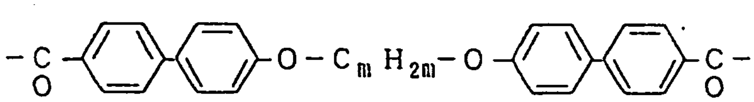
, ,

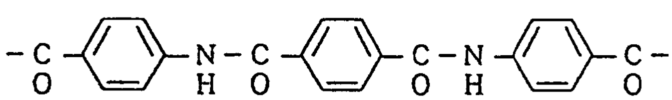
, ,

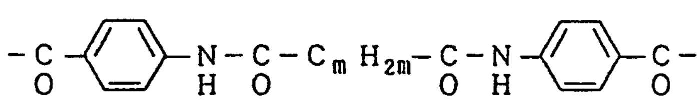
,

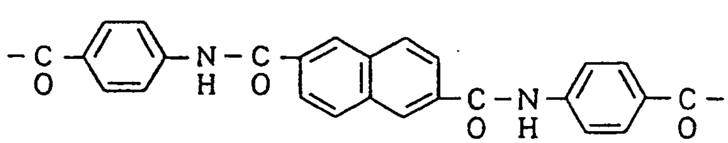
,

,

,

,

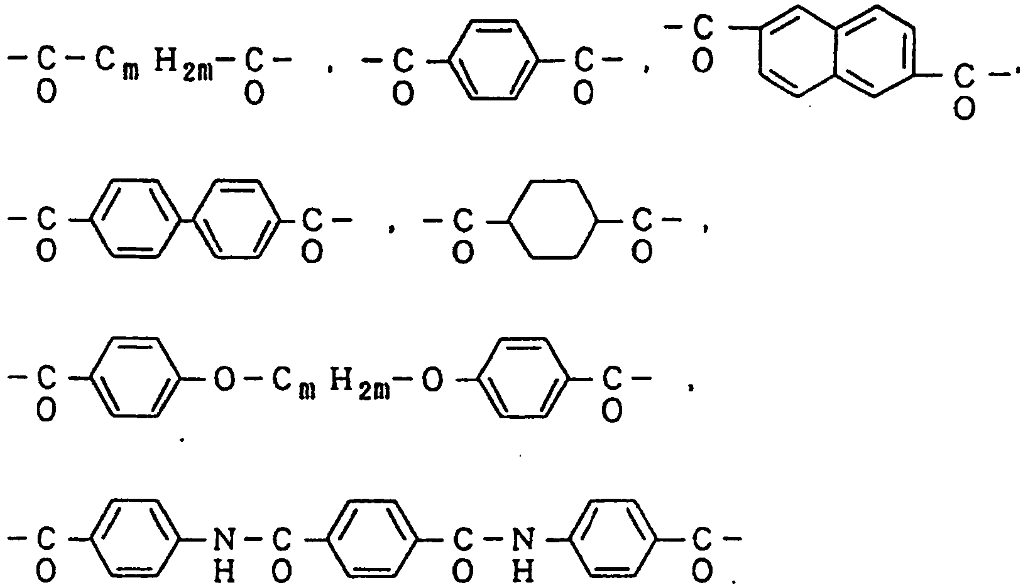
,



etc.

wherein m is an integer of 2-16.

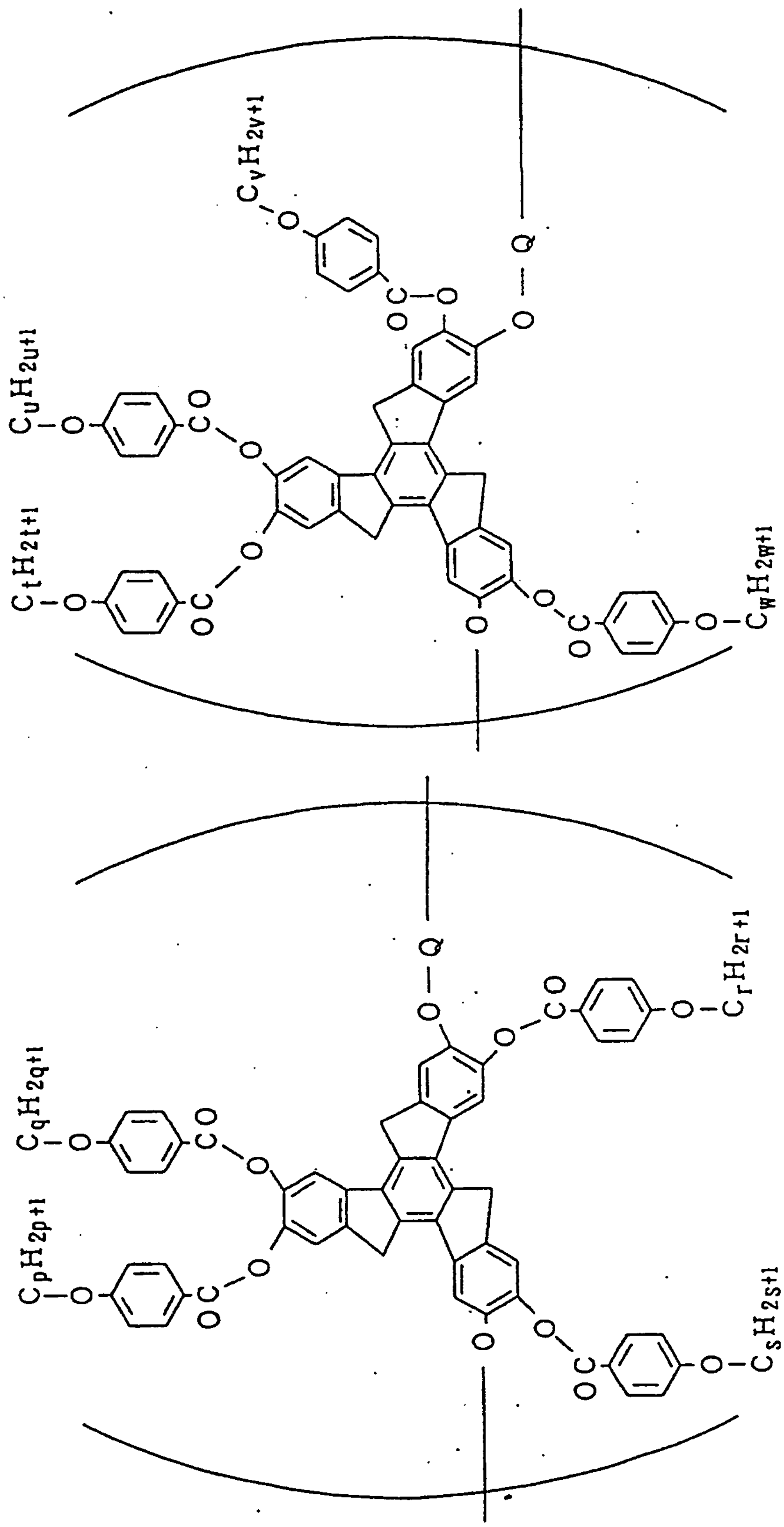
Preferable Q:



etc.

wherein m is an integer of 2-16, preferably 4-12.

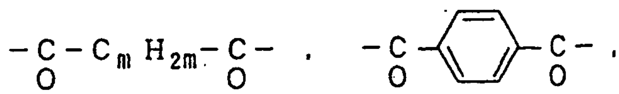
Polymer represented by the following:

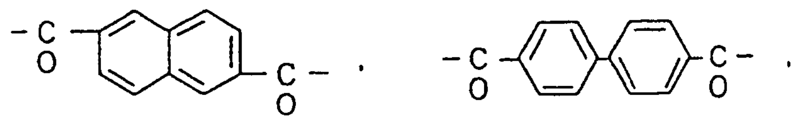


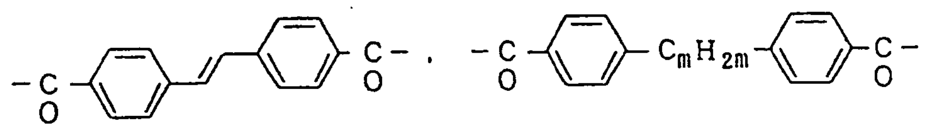
wherein p, q, r, s, t, u, v and w are each an integer of 1-18, preferably 3-14, and the average molecular weight is 5,000 - 100,000.

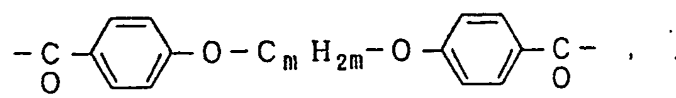
Q is the following:

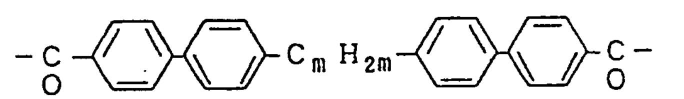
12.

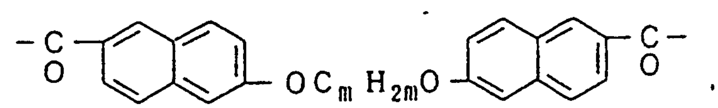


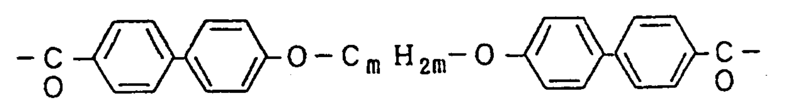


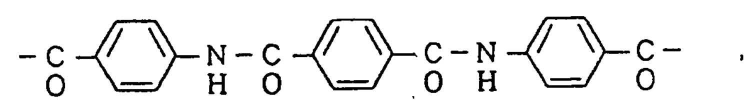


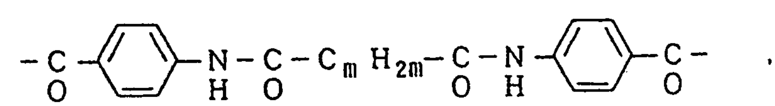


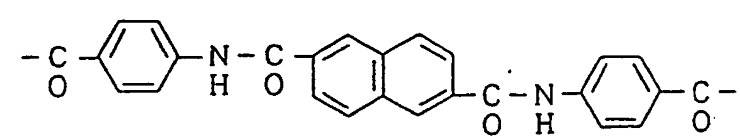








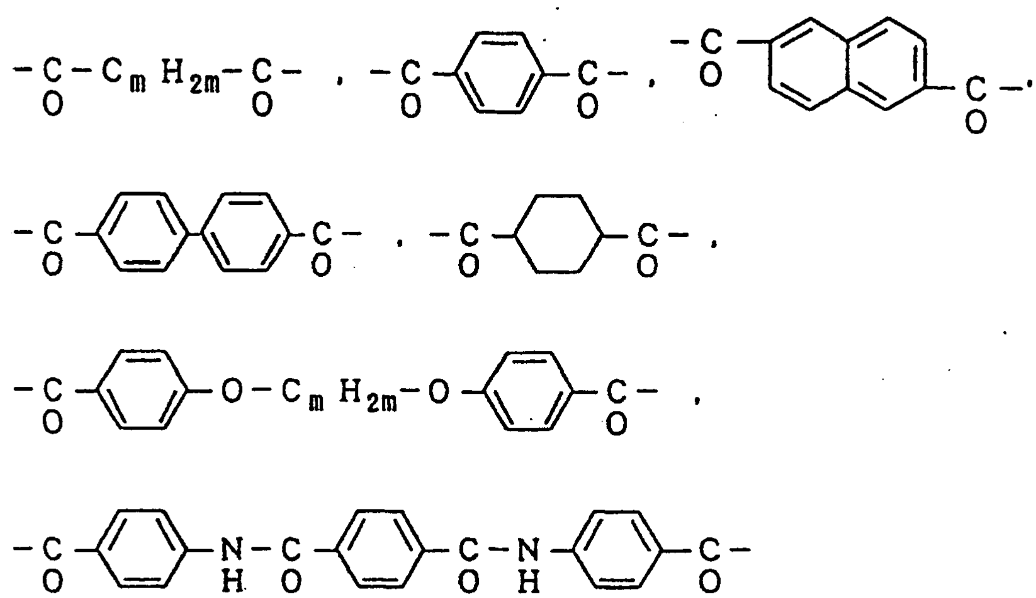




etc.

wherein m is an integer of 2-16.

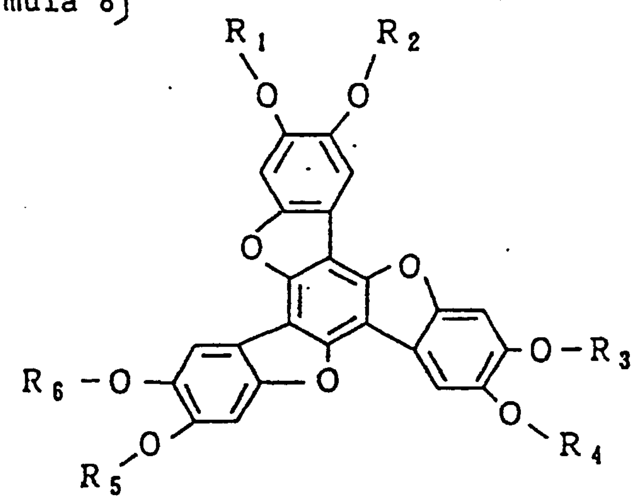
Preferable Q:



etc.

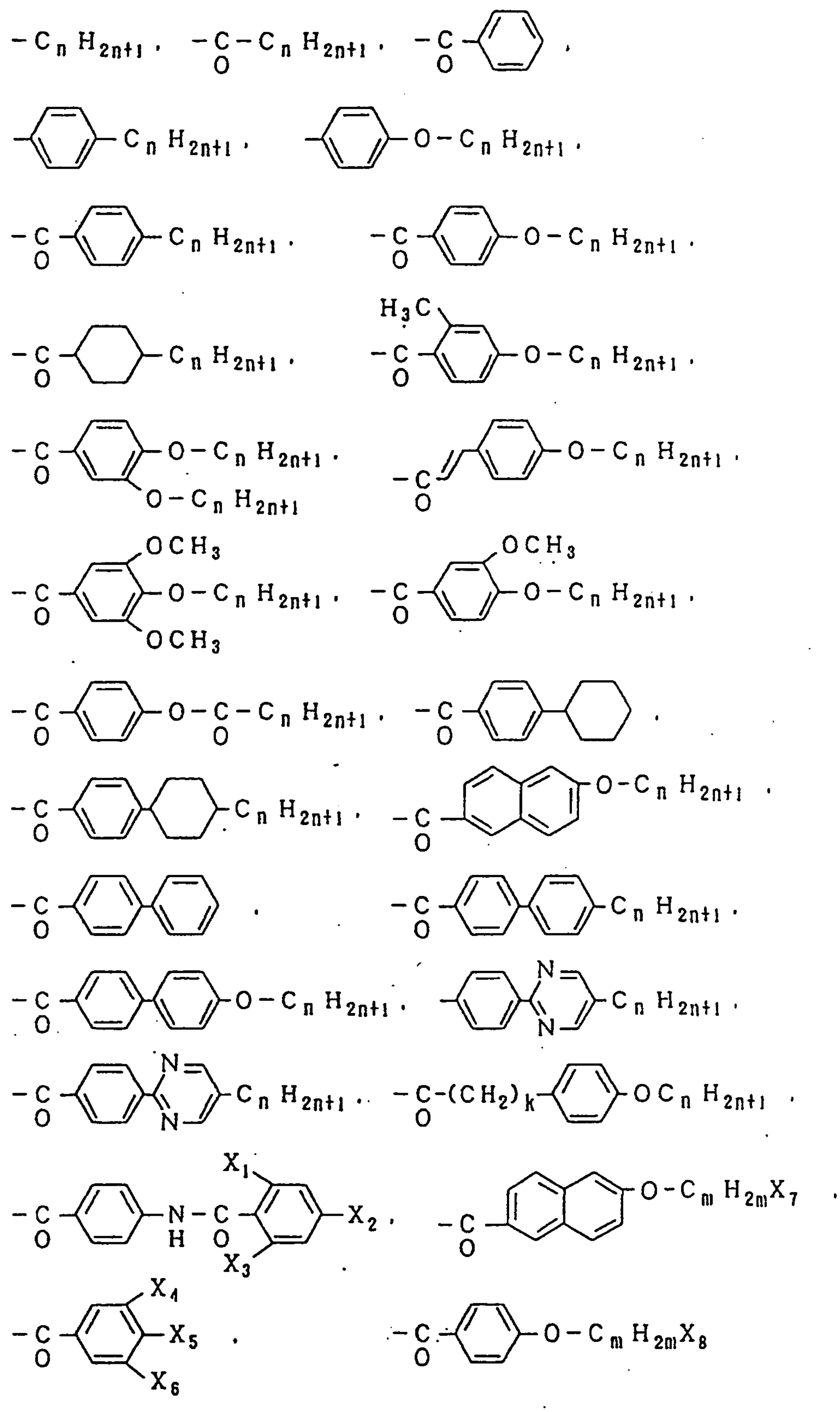
wherein m is an integer of 2-16, preferably 4-12.

[Structural formula 8]



wherein R_1-R_6 are each a monofunctional or bifunctional substituent group selected from the following groups:

Mono functional substituent groups:



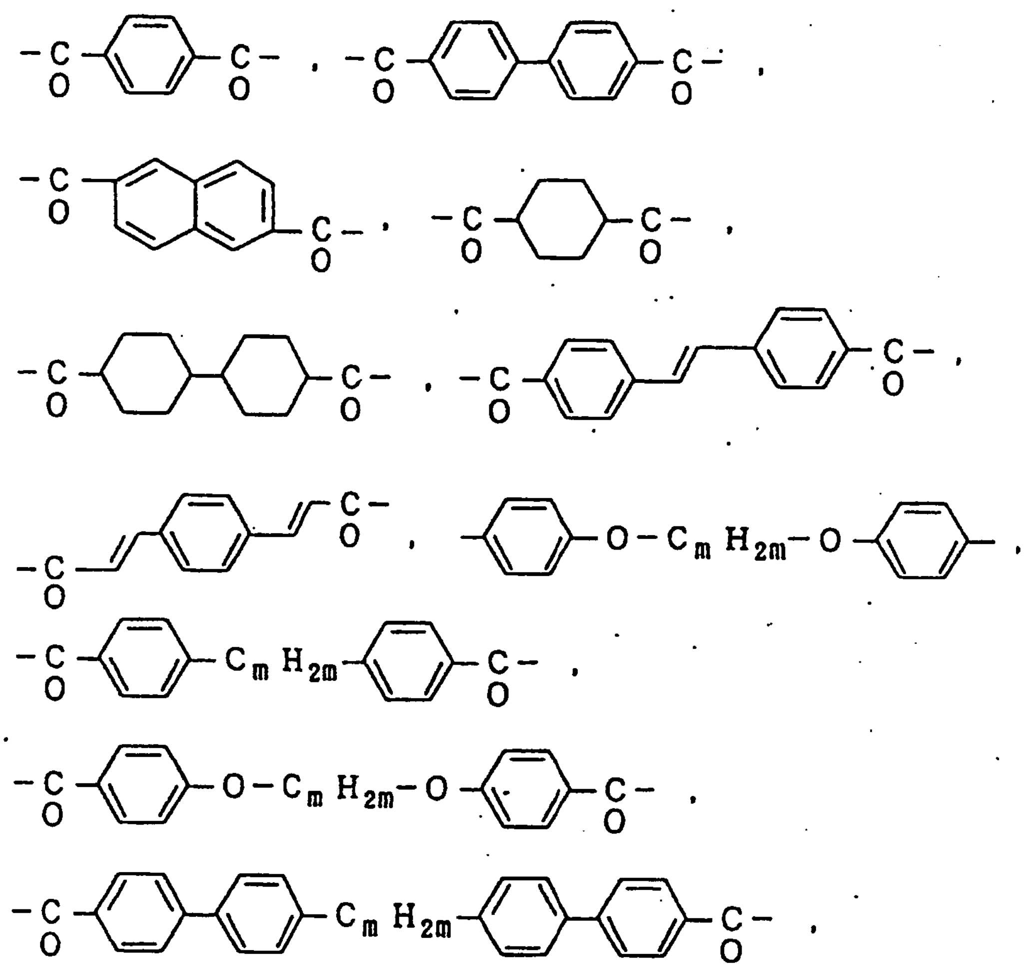
etc.

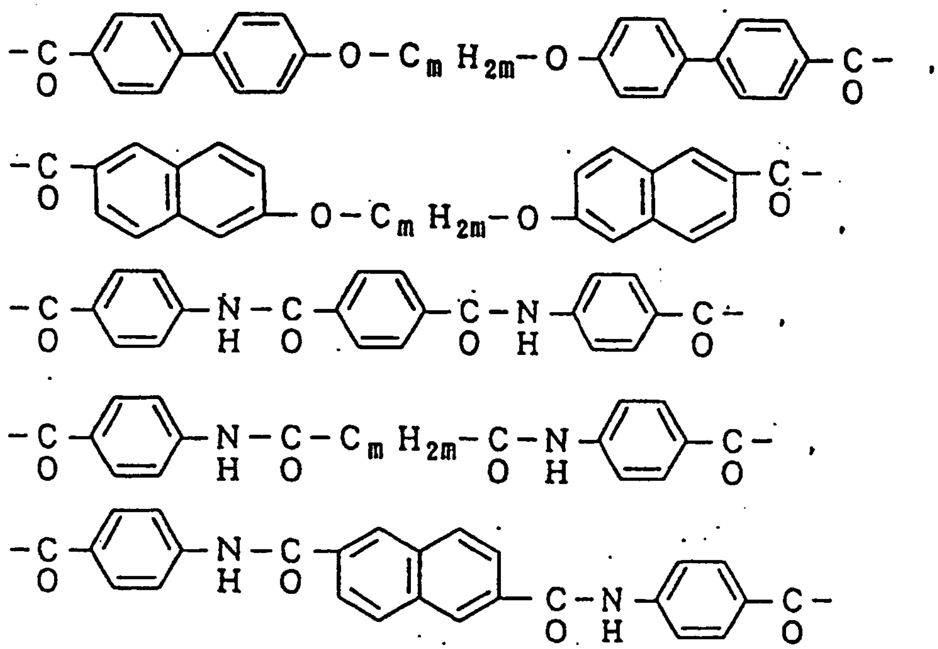
wherein C_nH_{2n+1} is a linear or branched alkyl group, n is an integer of 1-18, preferably 3-14, X_1-X_8 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, ℓ is an integer of 1-18, preferably 1-10, C_mH_{2m} is a linear or branched alkylene chain, and m is an integer of 1-

18, preferably 2-10.

Bifunctional substituent groups:

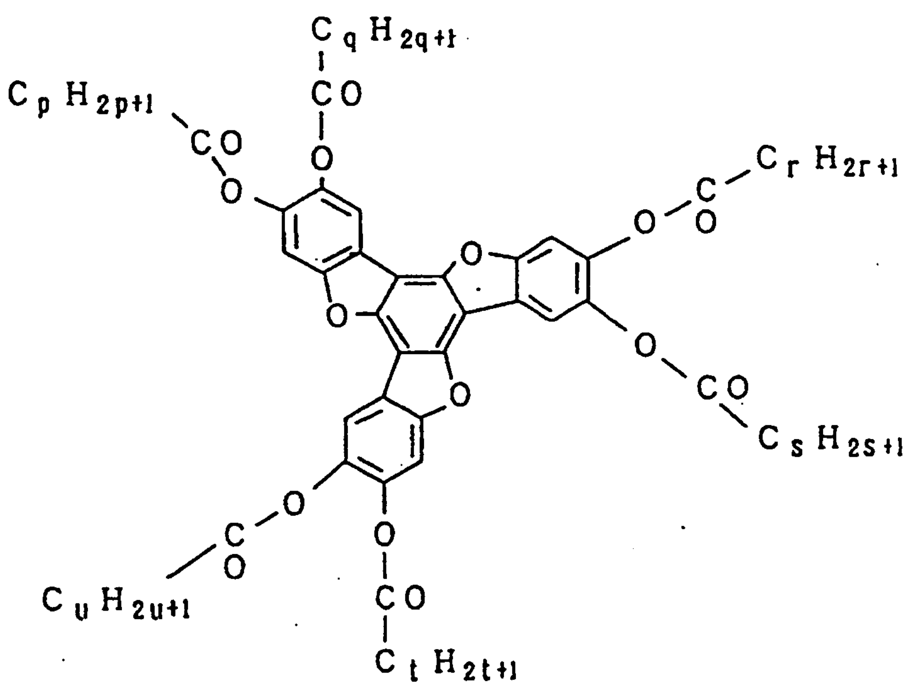
$$-C_mH_{2m}- \quad , \quad -\underset{O}{C}-C_mH_{2m}-\underset{O}{C}- \quad ,$$



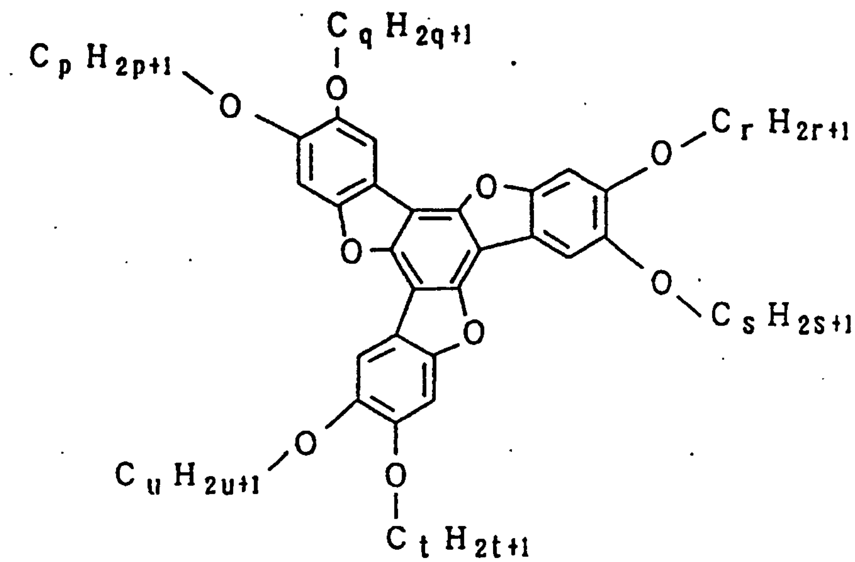


etc.

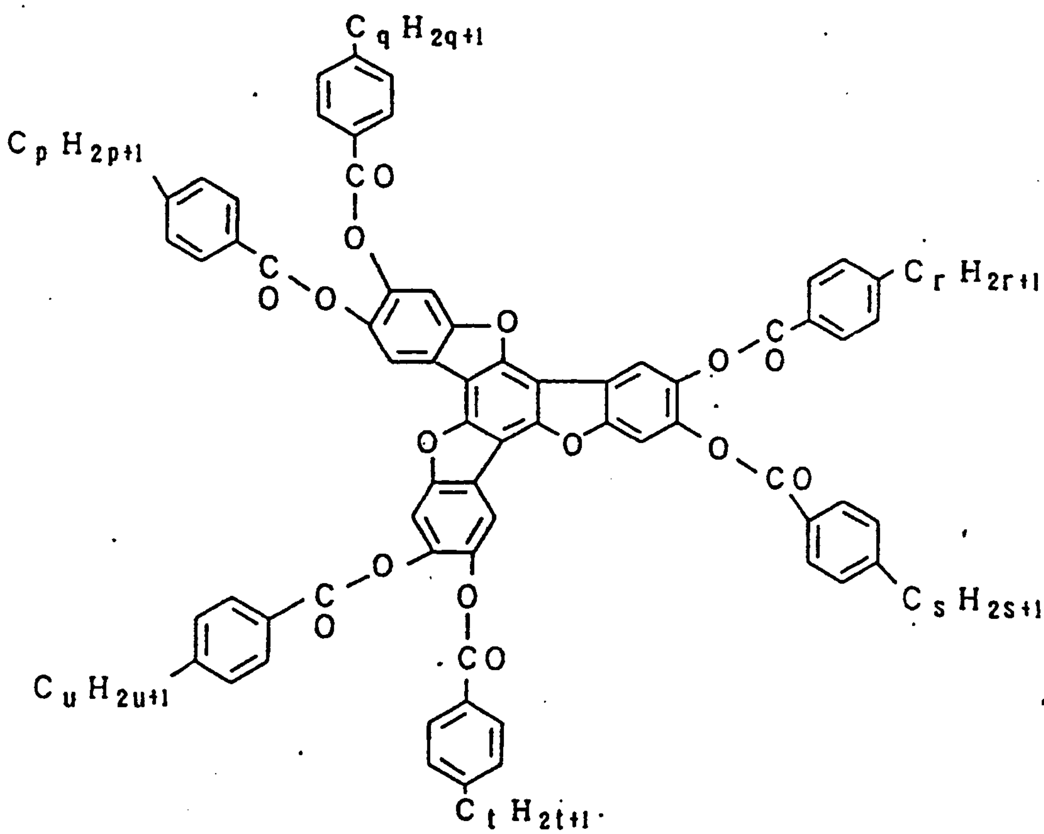
wherein C_mH_{2m} is a linear or branched alkylene chain, and m is an integer of 2-16, preferably 4-12. Examples of the concrete structures:



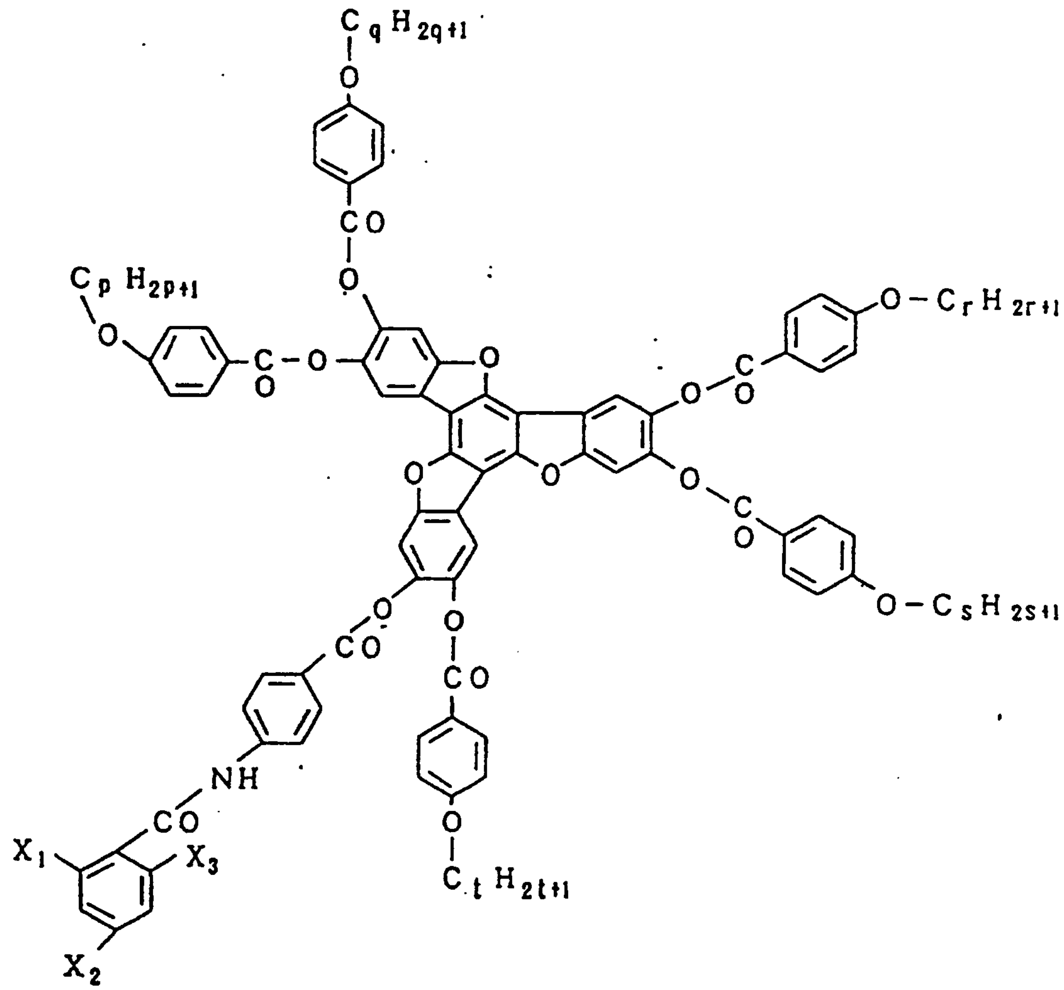
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



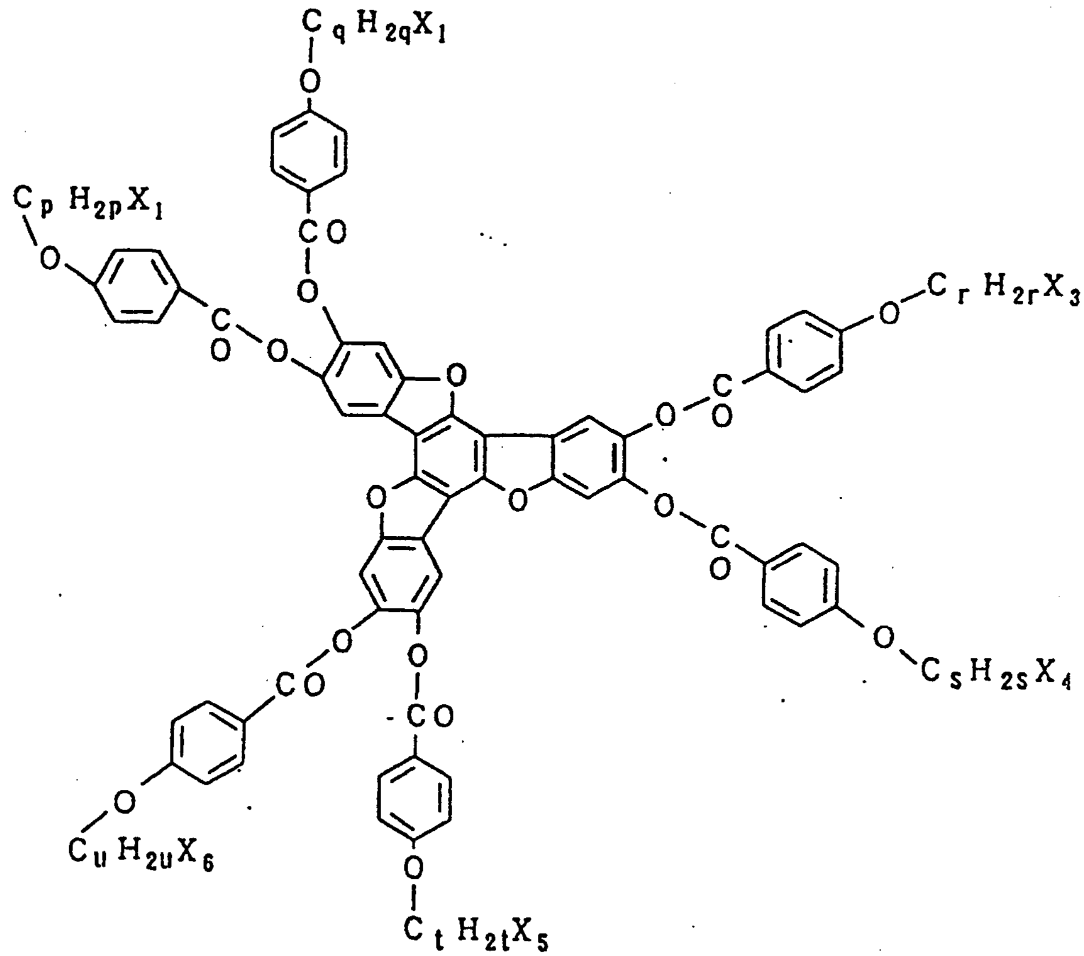
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



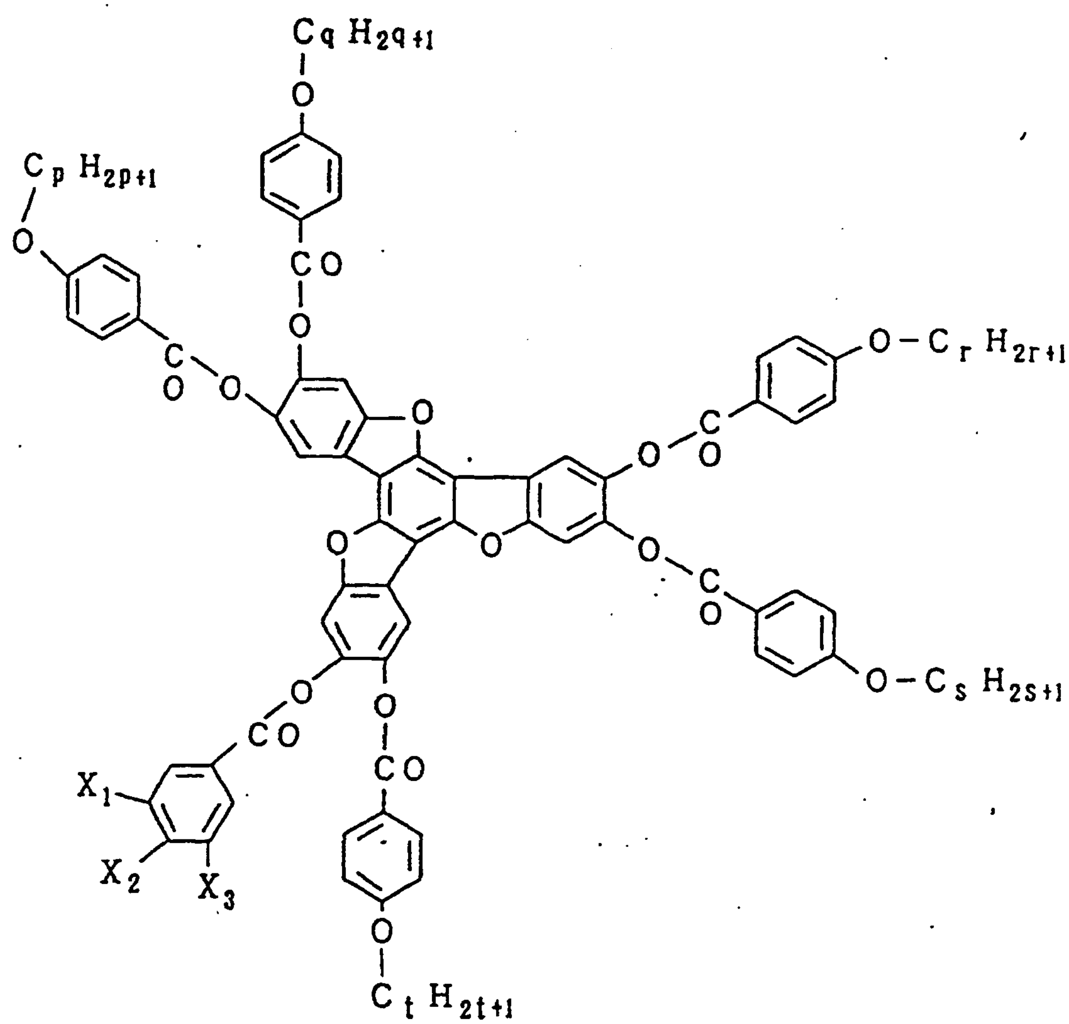
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



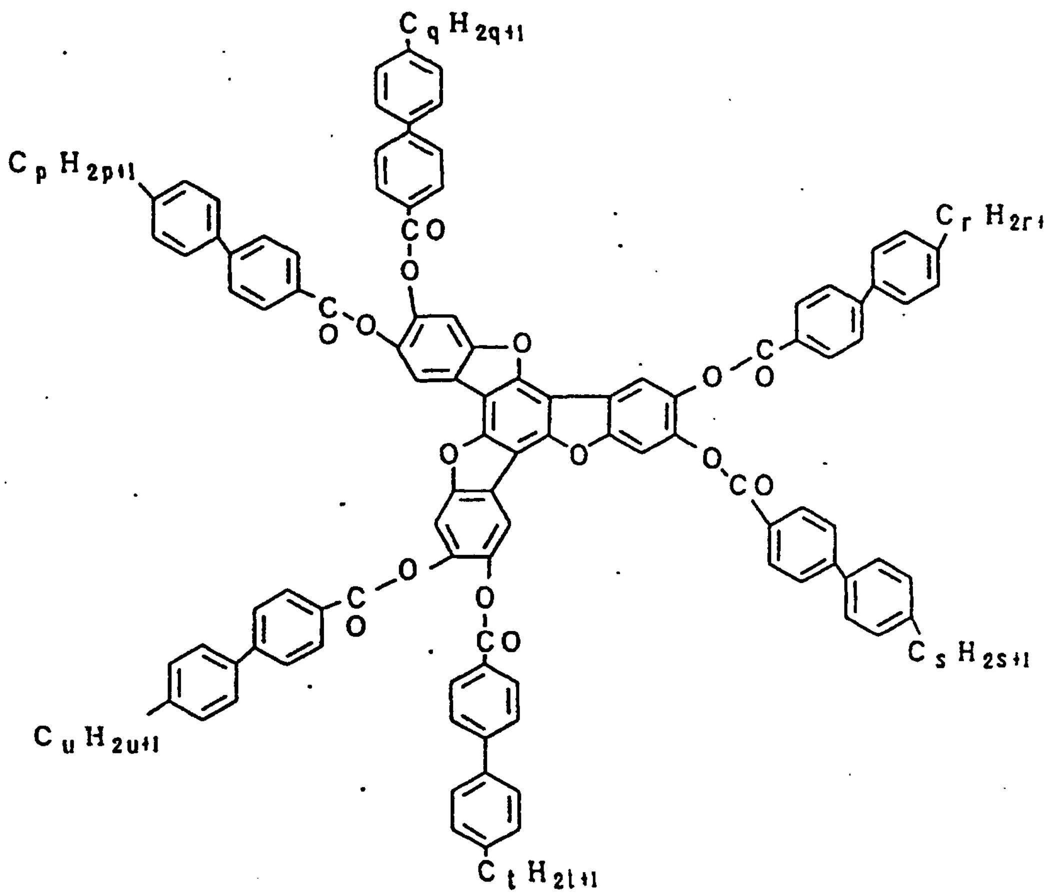
wherein p, q, r, s and t are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



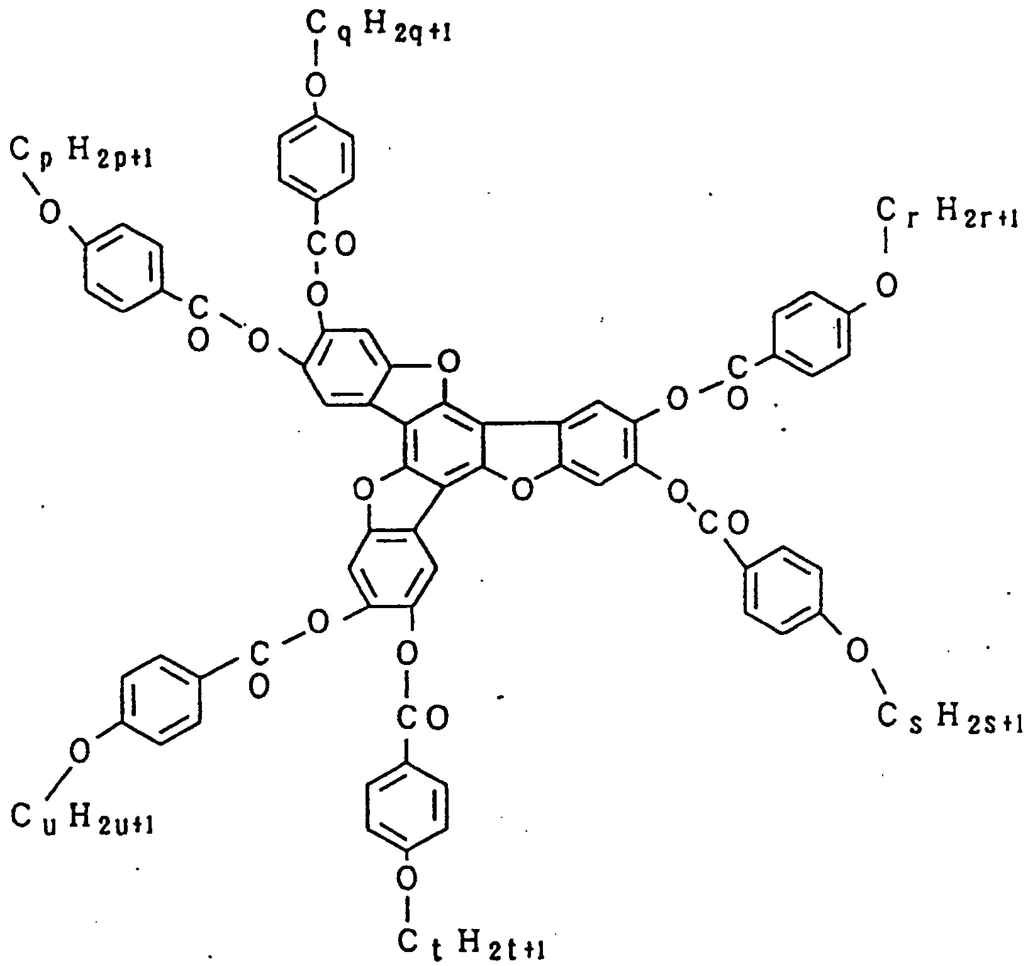
wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14, X_1-X_6 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



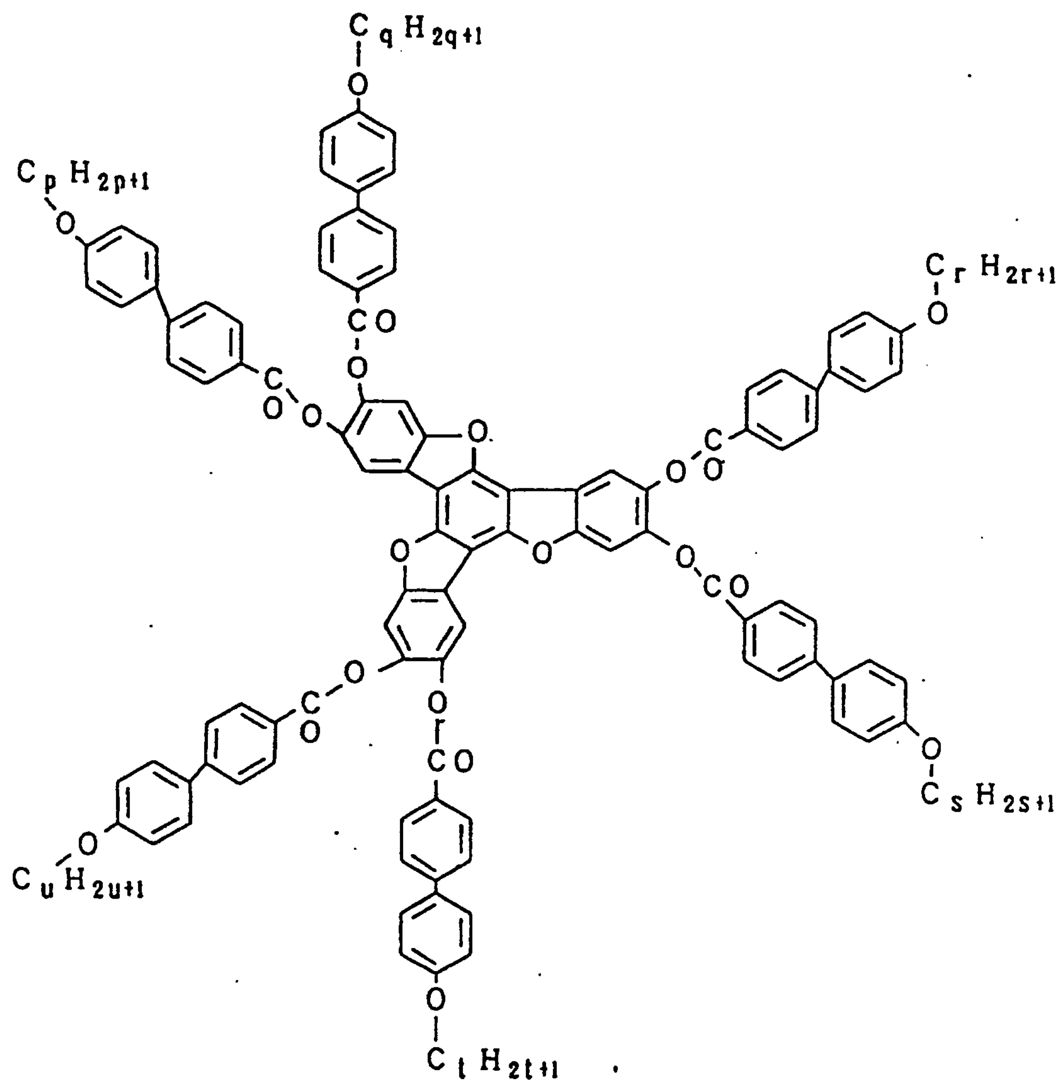
wherein p, q, r, s and t are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

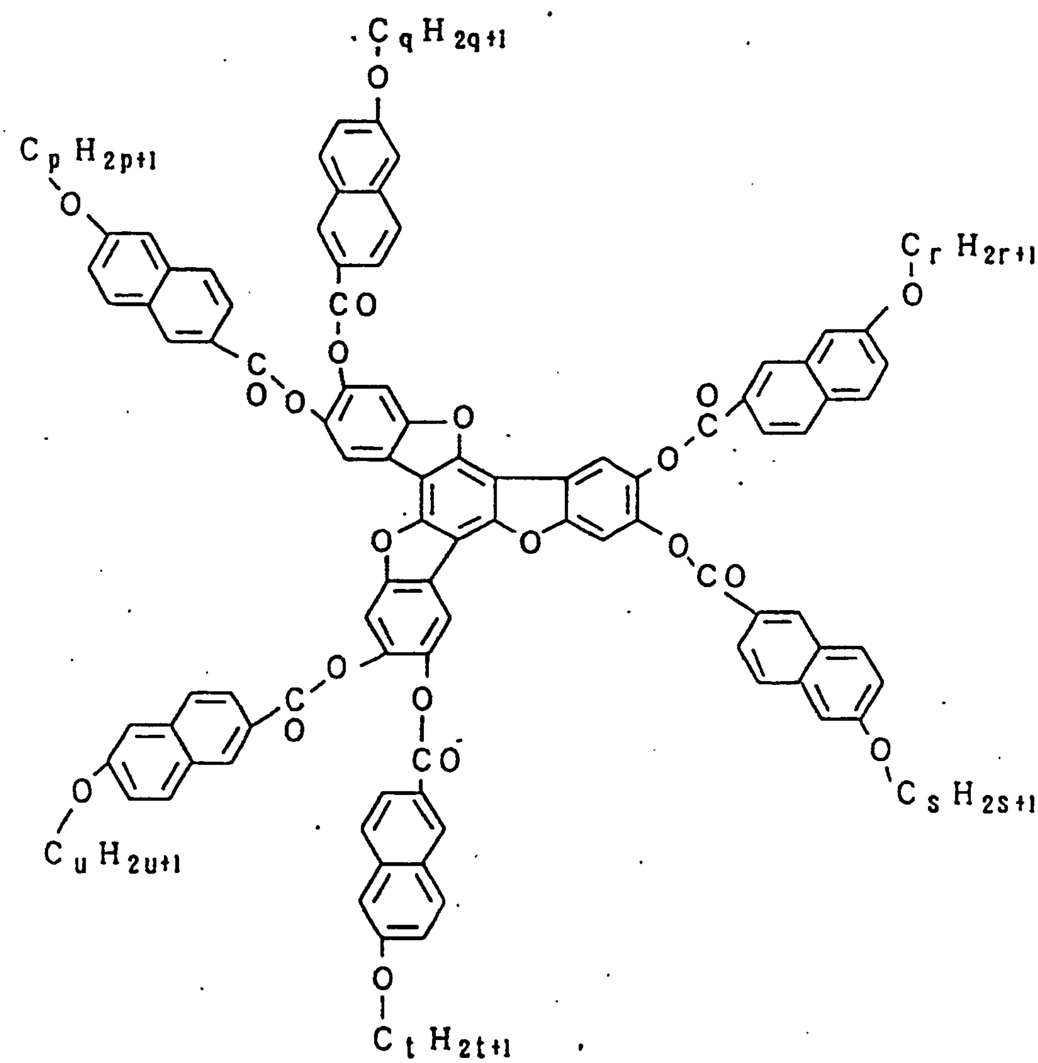


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14

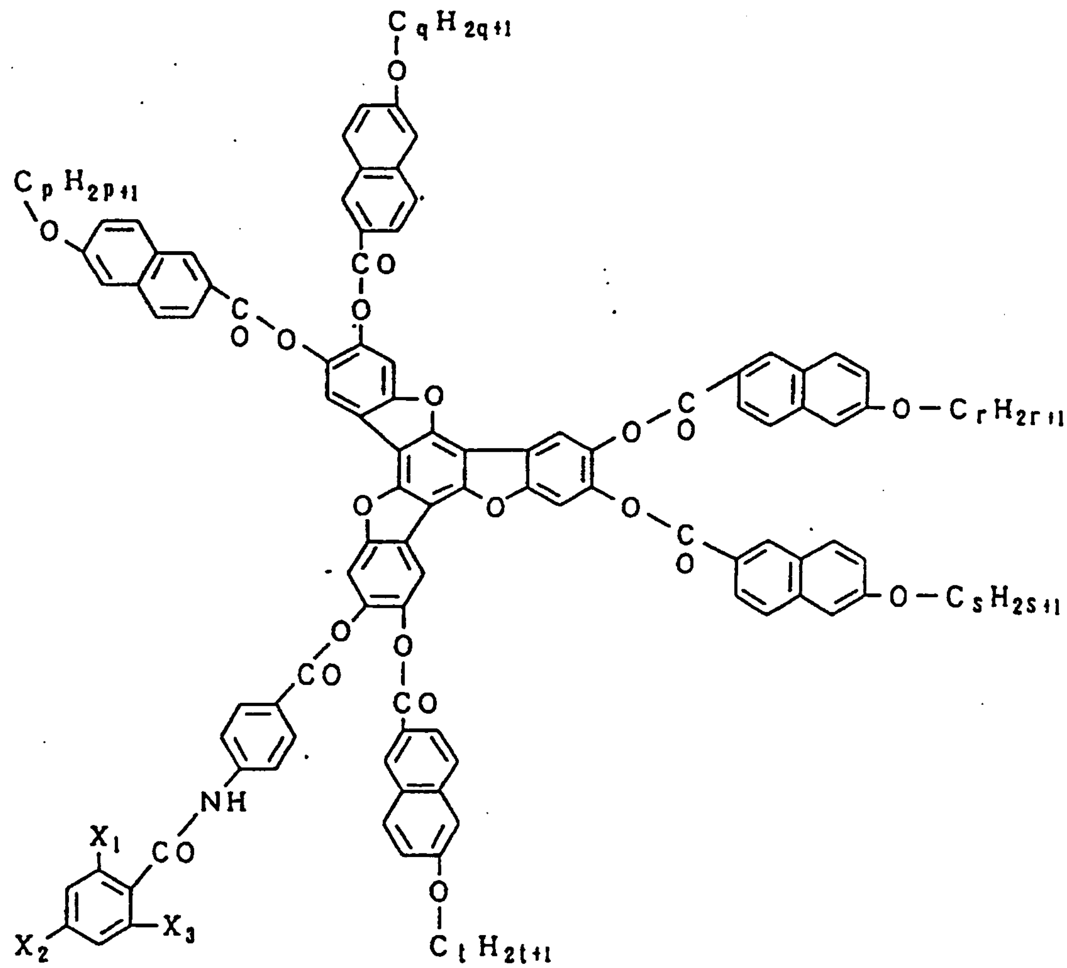


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.

13-

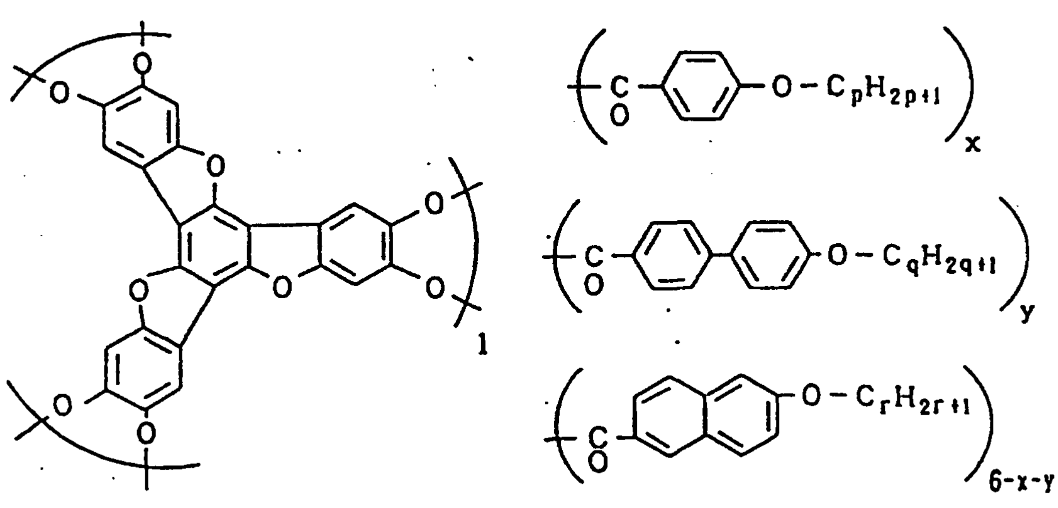


wherein p, q, r, s, t and u are each an integer of 1-18, preferably 3-14.



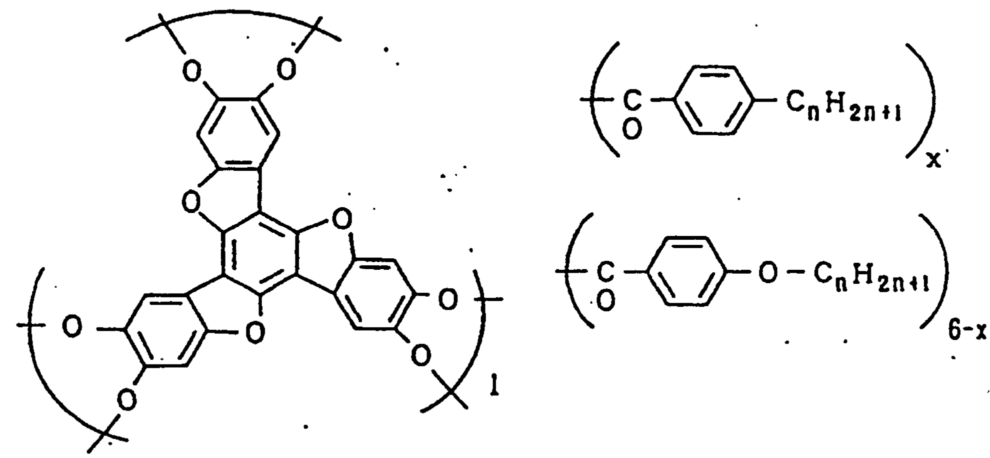
wherein p, q, r, s and t are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

Composition of the following:



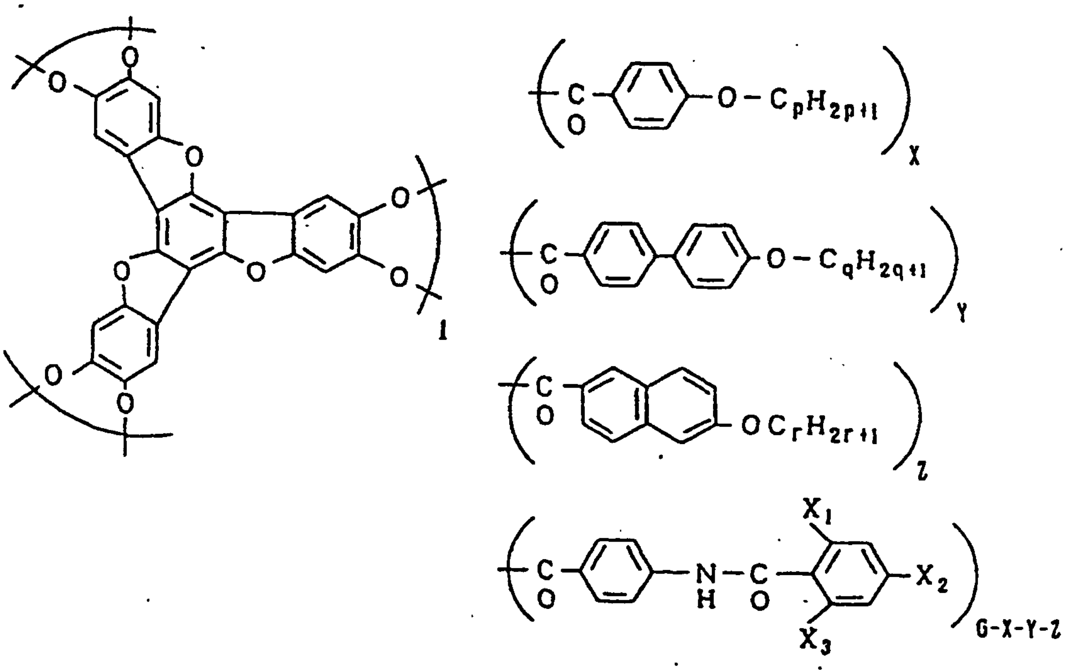
wherein $0 \leqq x \leqq 6$, $0 \leqq y \leqq 6$ in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14.

Composition of the following:



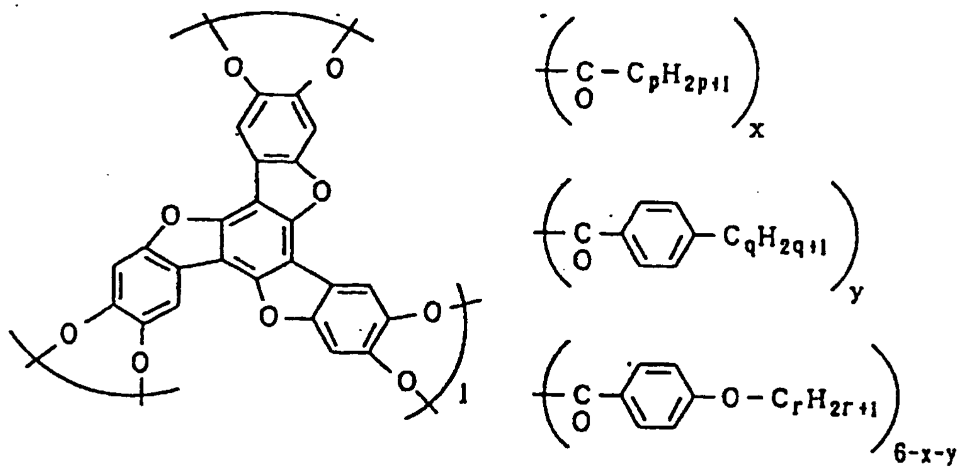
wherein $0 \leq x \leq 6$ in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14.

Composition of the following:



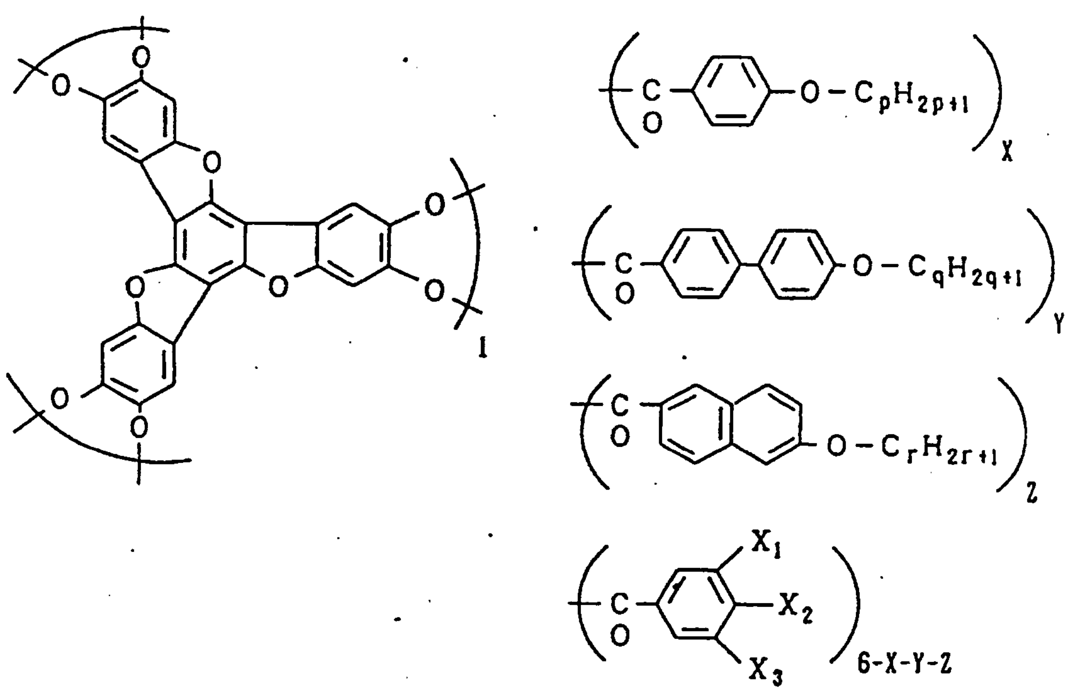
wherein $0 \leq x \leq 6$, $0 \leq y \leq 6$, $0 \leq z \leq 6$ in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_{\ell}H_{2\ell+1}$, $C_{\ell}H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_{\ell}H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

Composition of the following:



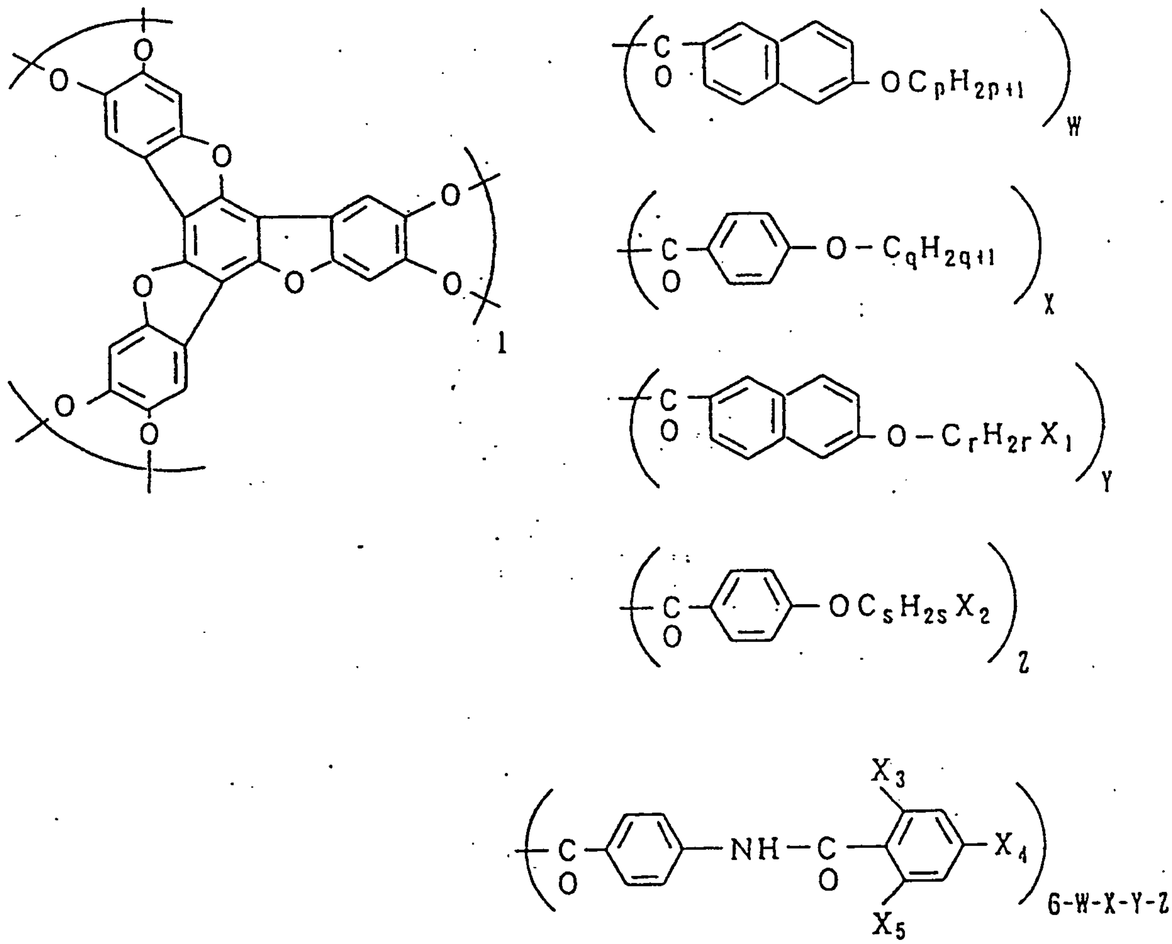
wherein 0≦x≦6, 0≦y≦6 in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14.

Composition of the following:

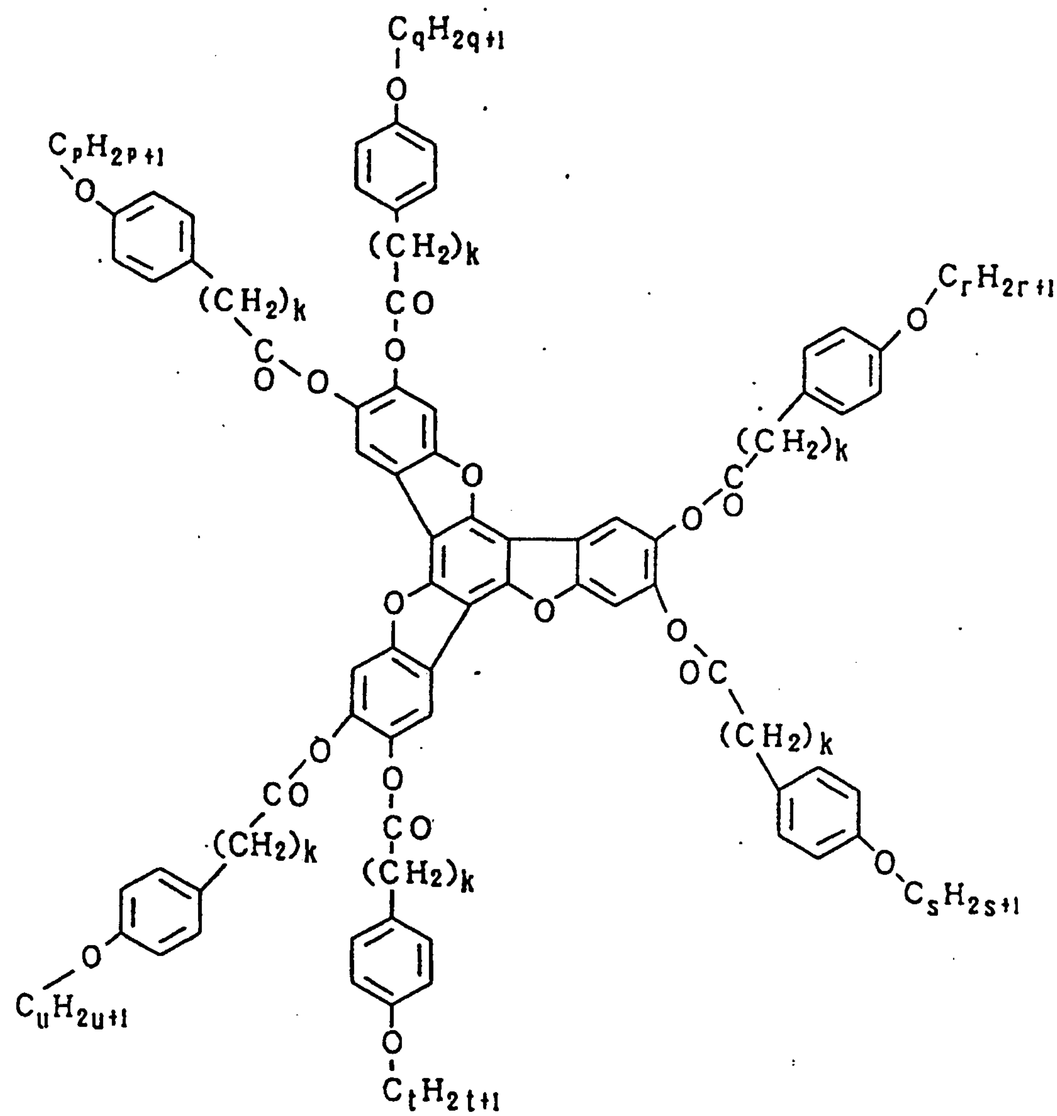


wherein 0≦x≦6, 0≦y≦6, 0≦z≦6 in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14, X_1-X_3 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.

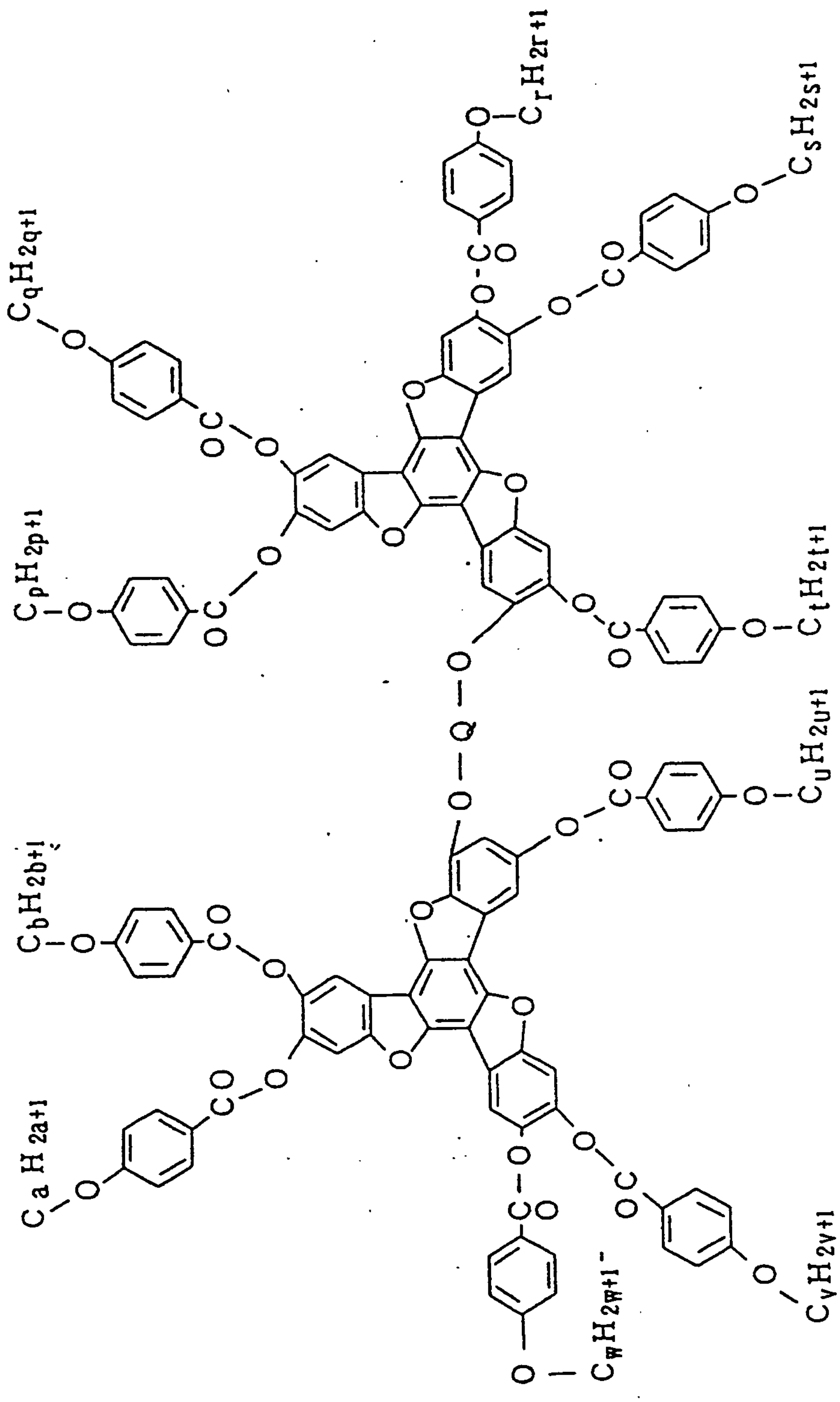
Composition of the following:



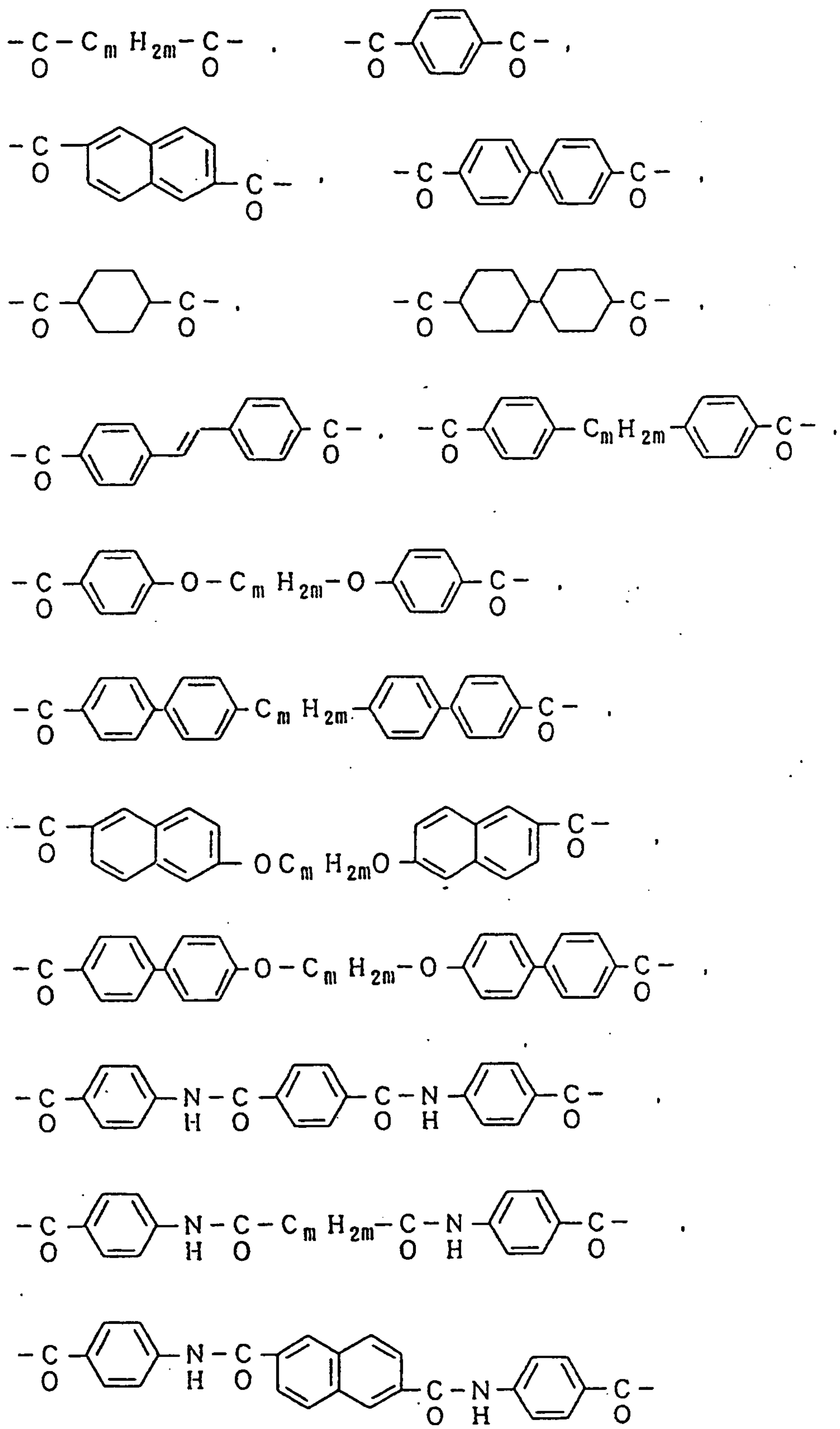
wherein $0 \leqq x \leqq 6$, $0 \leqq y \leqq 6$, $0 \leqq z \leqq 6$ in the molar ratio, and p, q and r are each an integer of 1-18, preferably 3-14, X_1-X_5 are each independently H-, F-, Cl-, Br-, $C_\ell H_{2\ell+1}$, $C_\ell H_{2\ell+1}O$-, C_6H_5-, C_6H_5CO- or C_6H_5O-, where $C_\ell H_{2\ell+1}$ is a linear or branched alkyl group, and ℓ is an integer of 1-18, preferably 1-10.



wherein p, q, r, s, t, u, v and w are each an integer of 3-18, preferably 5-14, k is 1, 2 or 3.



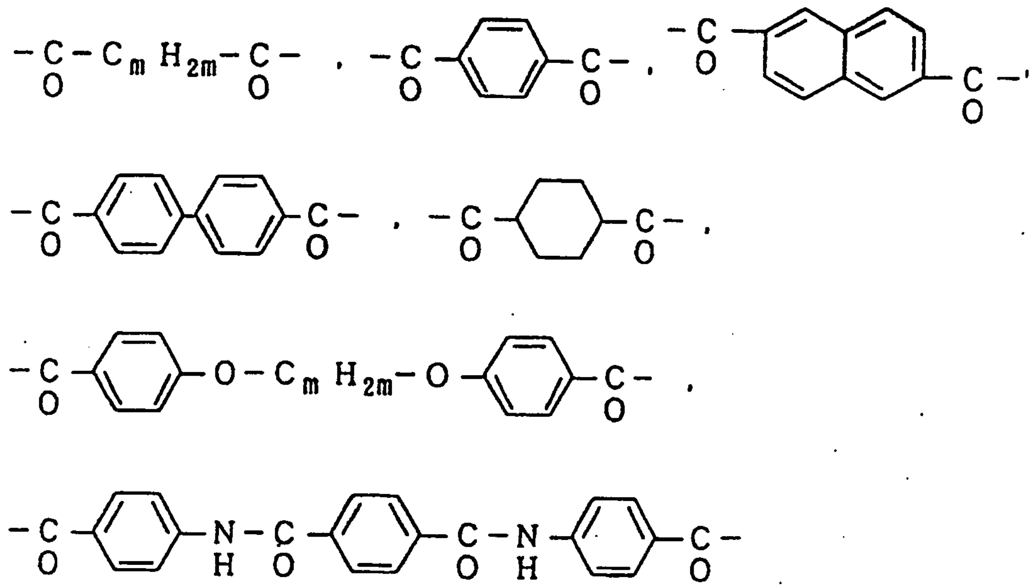
wherein p, q, r, s, t, u, v, w, a and b are each an integer of 1-18, preferably 3-14.
Q is the following:



etc.

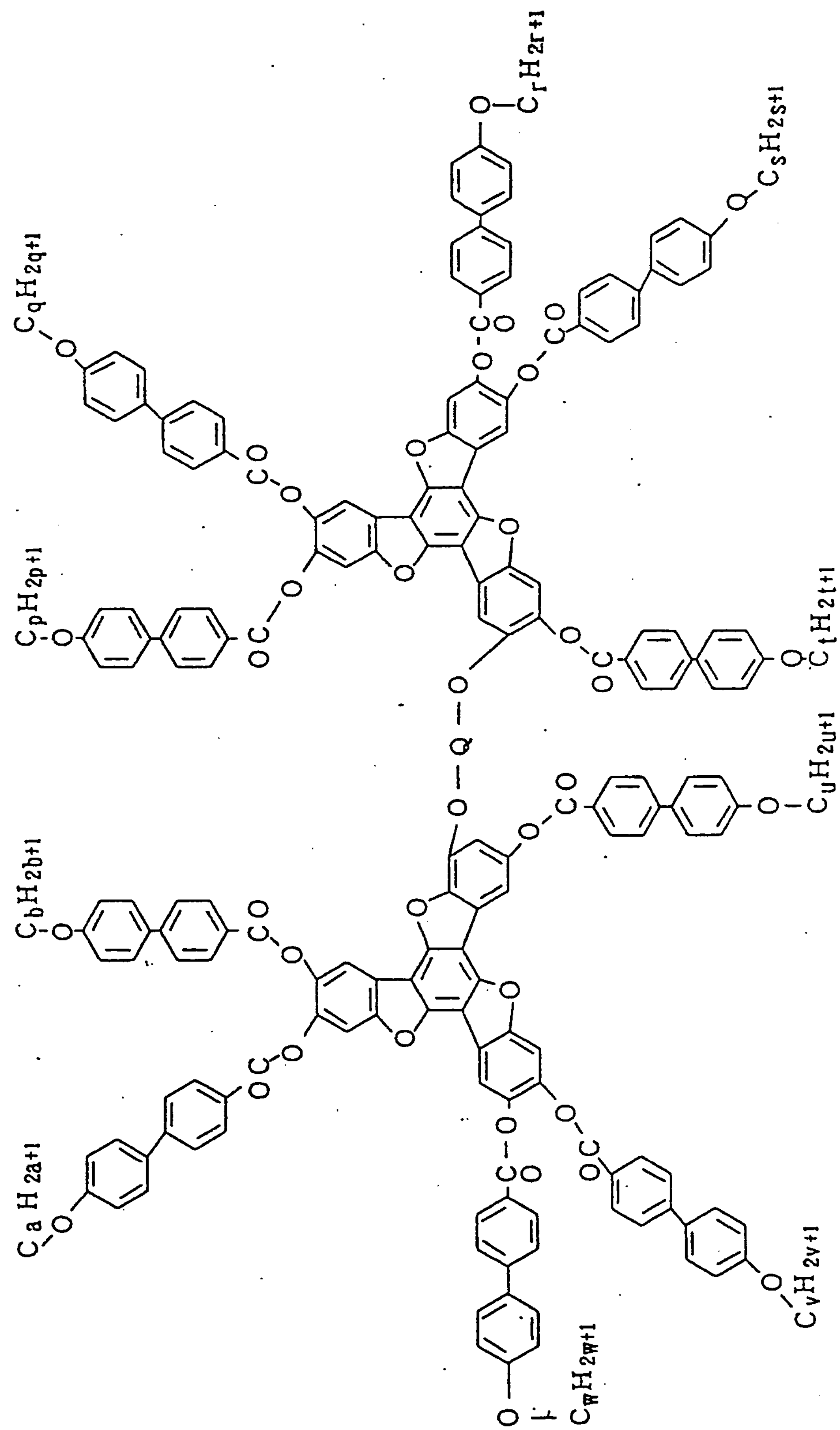
wherein m is an integer of 2-16.

Preferable Q:



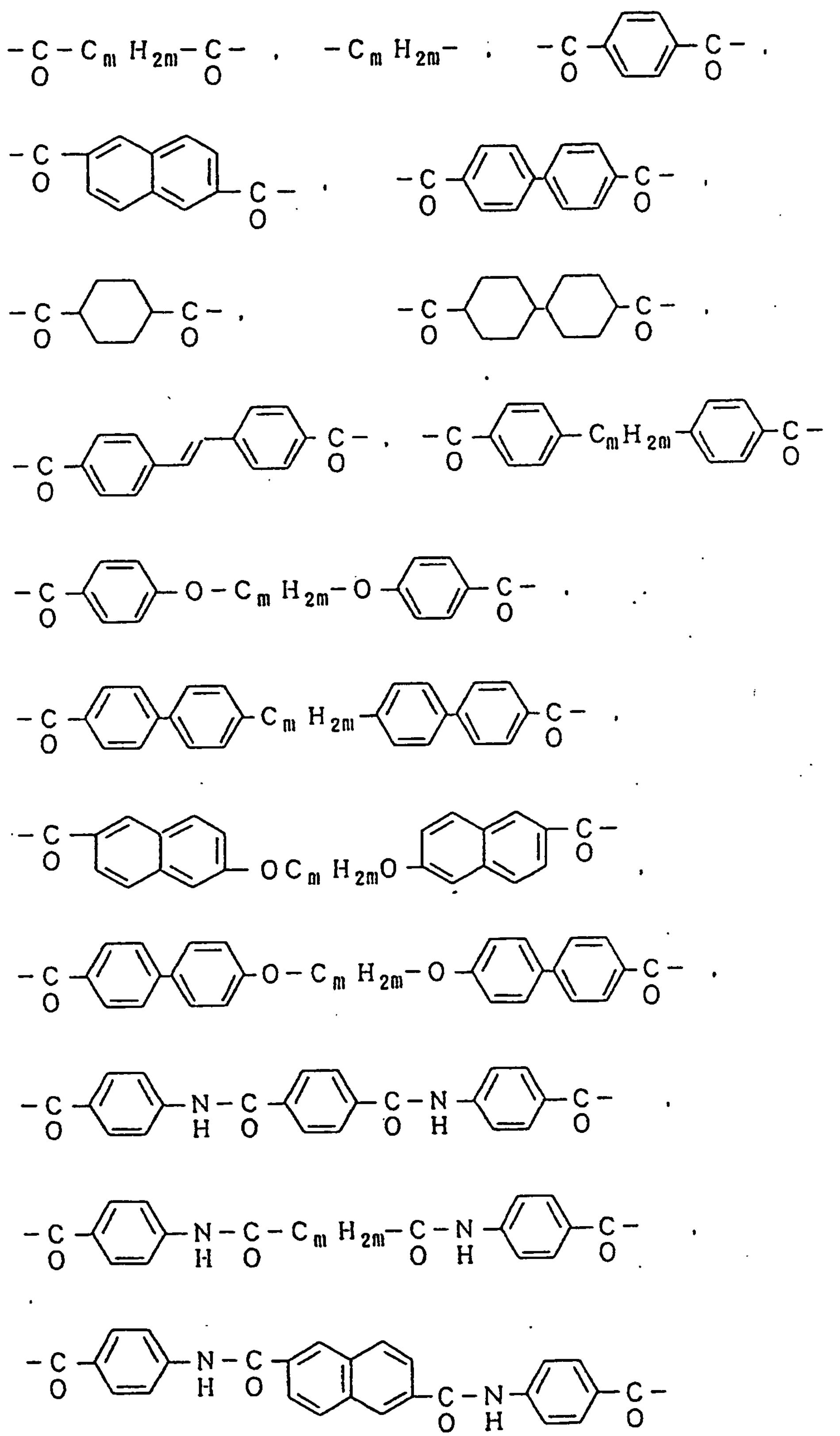
etc.

wherein m is an integer of 2-16, preferably 4-12.



wherein p, q, r, s, t, u, v, w, a and b are each an integer of 1-18, preferably 3-14.

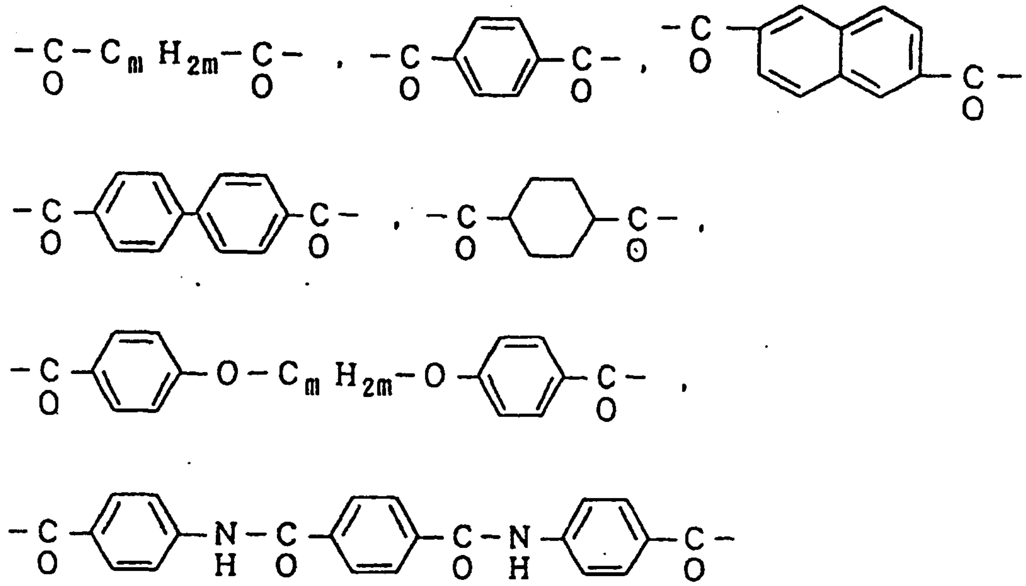
Q is the following:



etc.

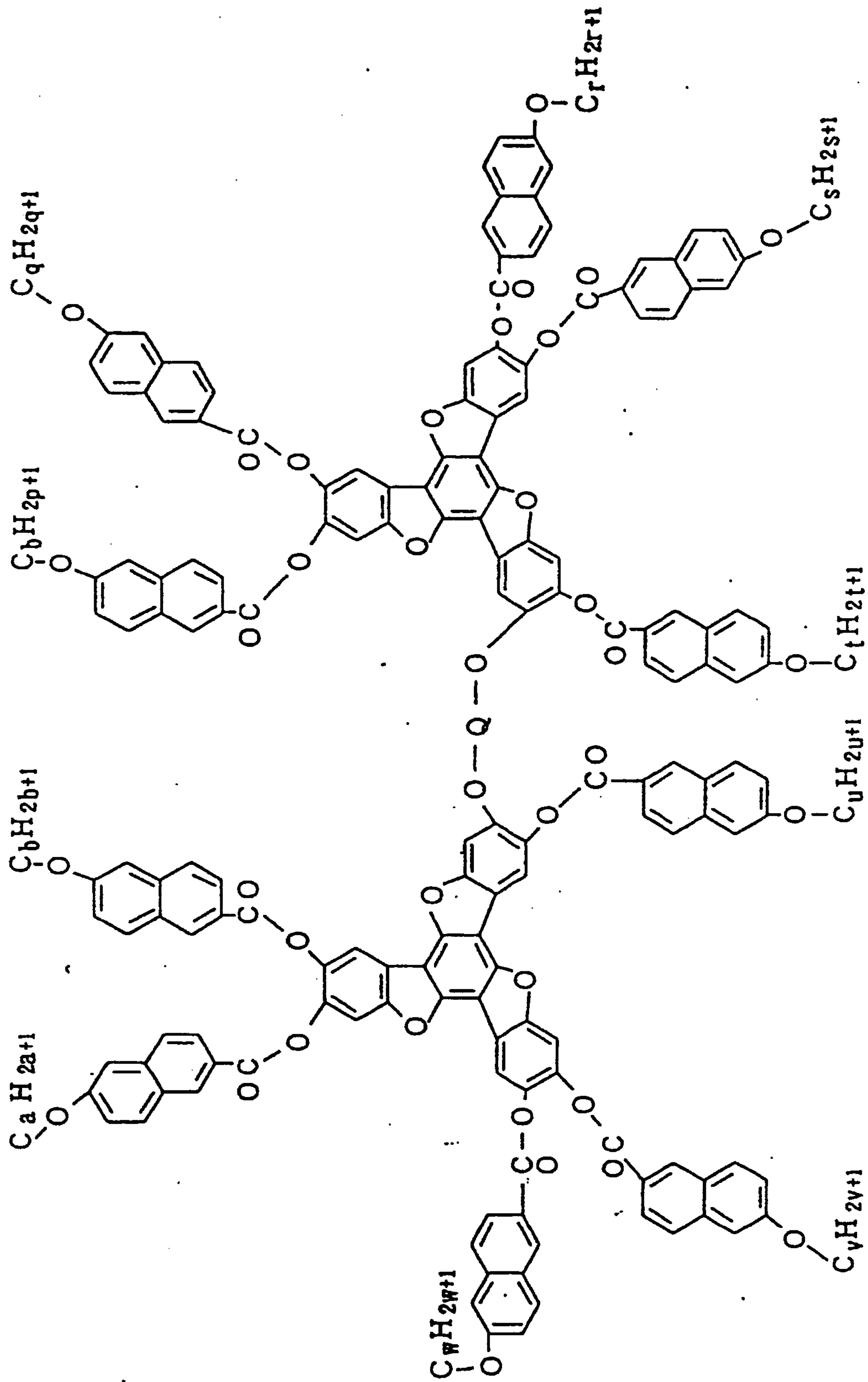
wherein m is an integer of 2-16.

Preferable Q:

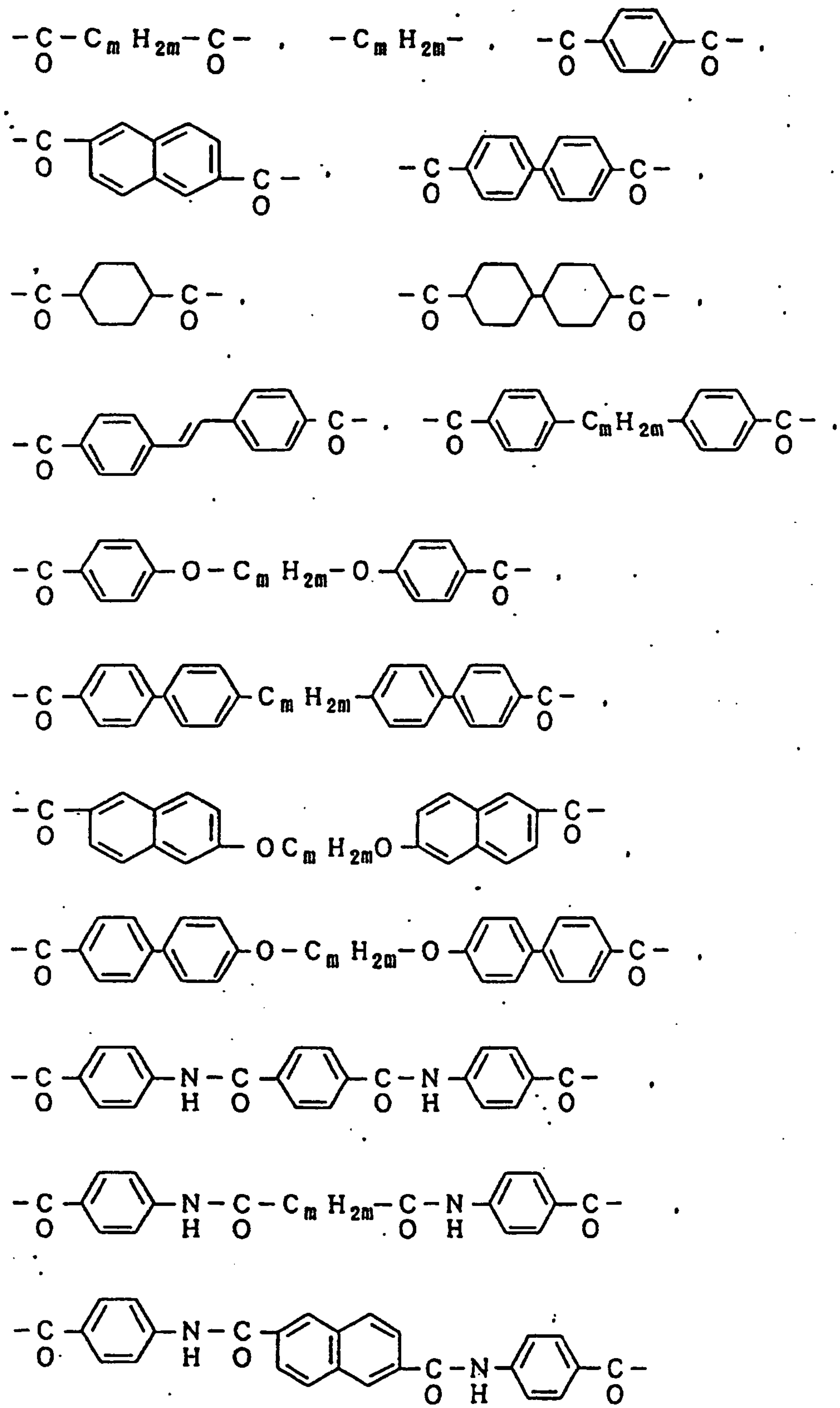


etc.

wherein *m* is an integer of 2-16, preferably 4-12.



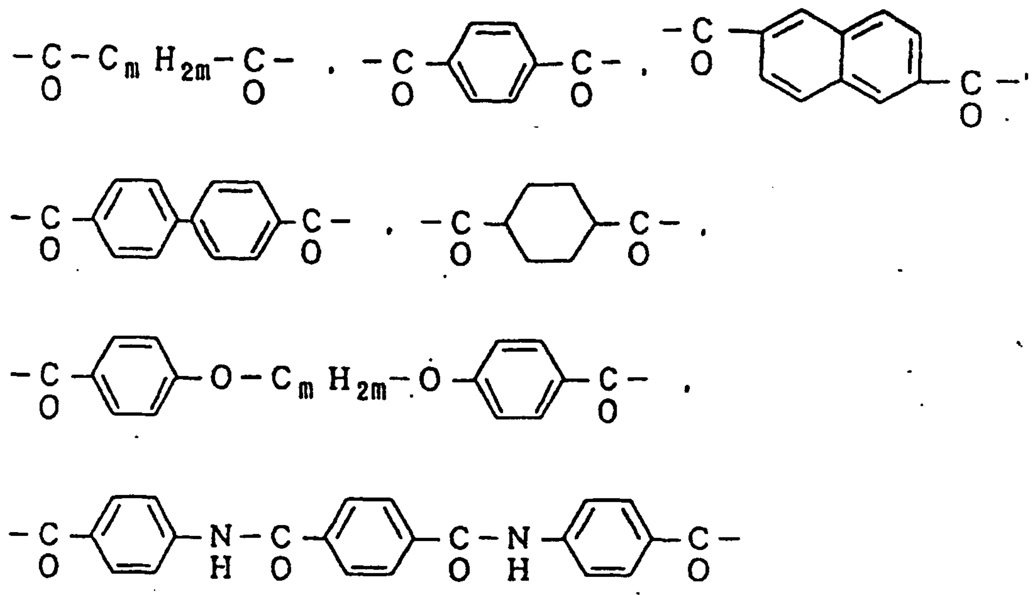
wherein p, q, r, s, t, u, v, w, a and b are each an integer of 1-18, preferably 3-14.
Q is the following:



etc.

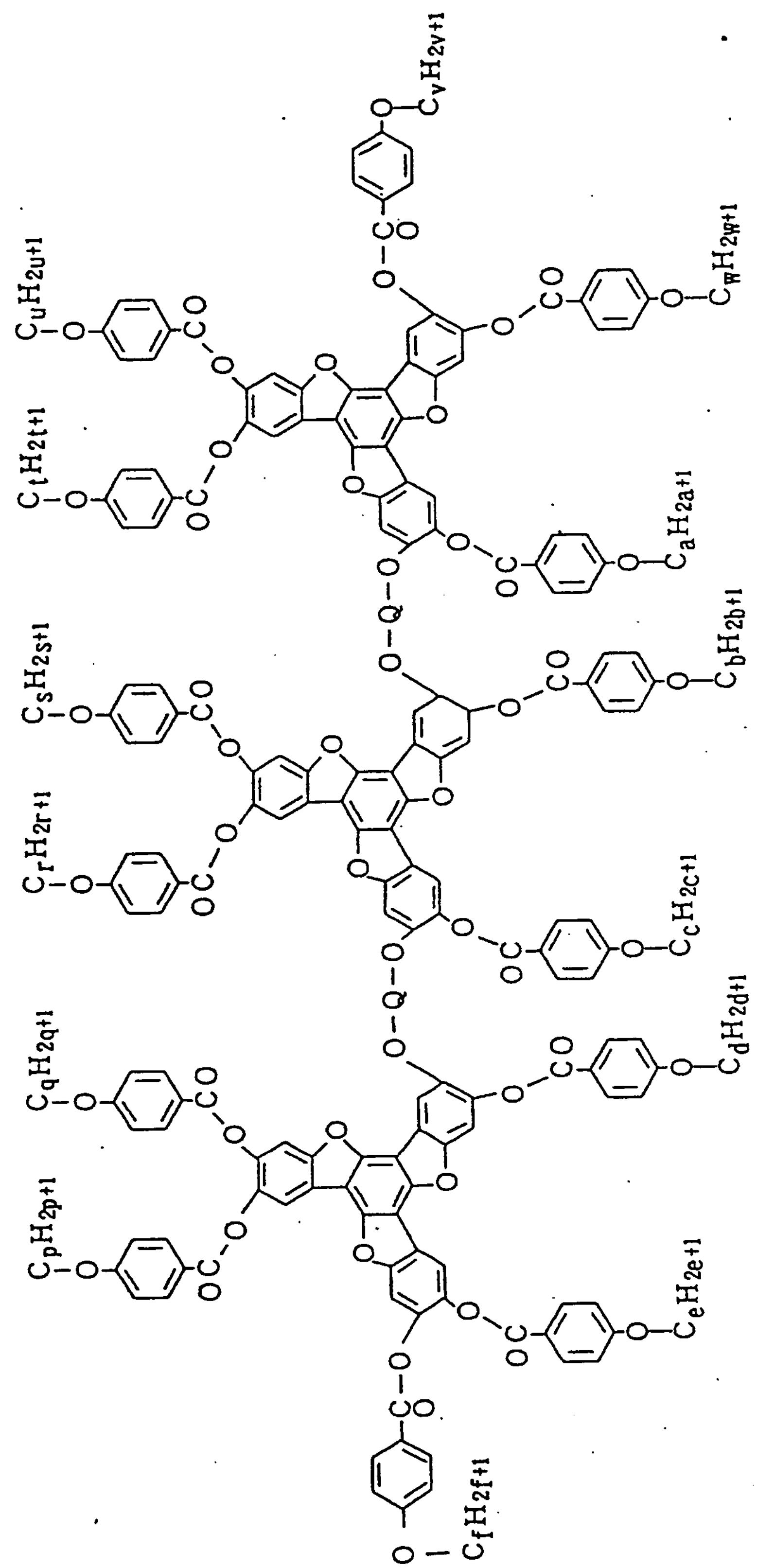
wherein m is an integer of 2-16.

Preferable Q:

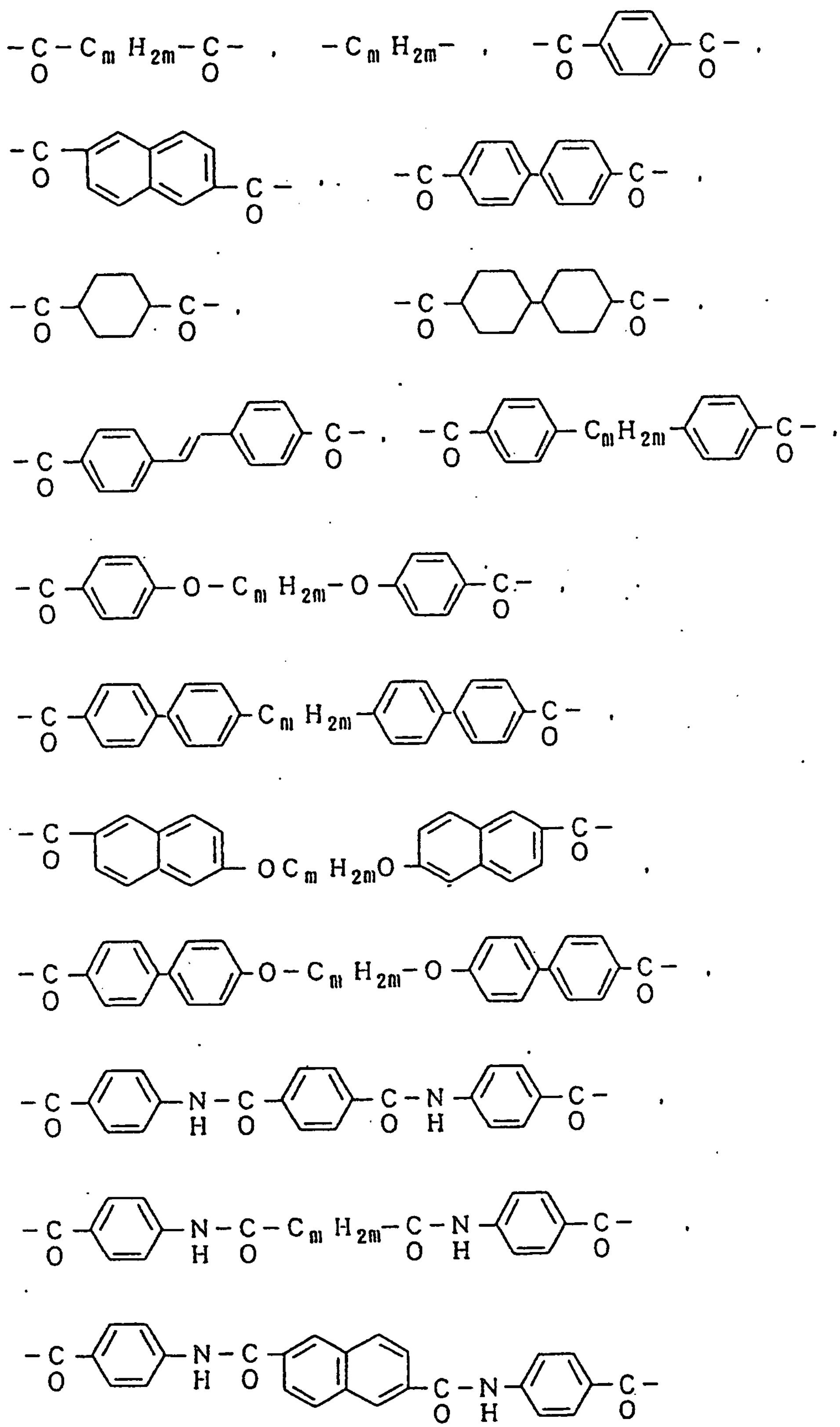


etc.

wherein m is an integer of 2-16, preferably 4-12.



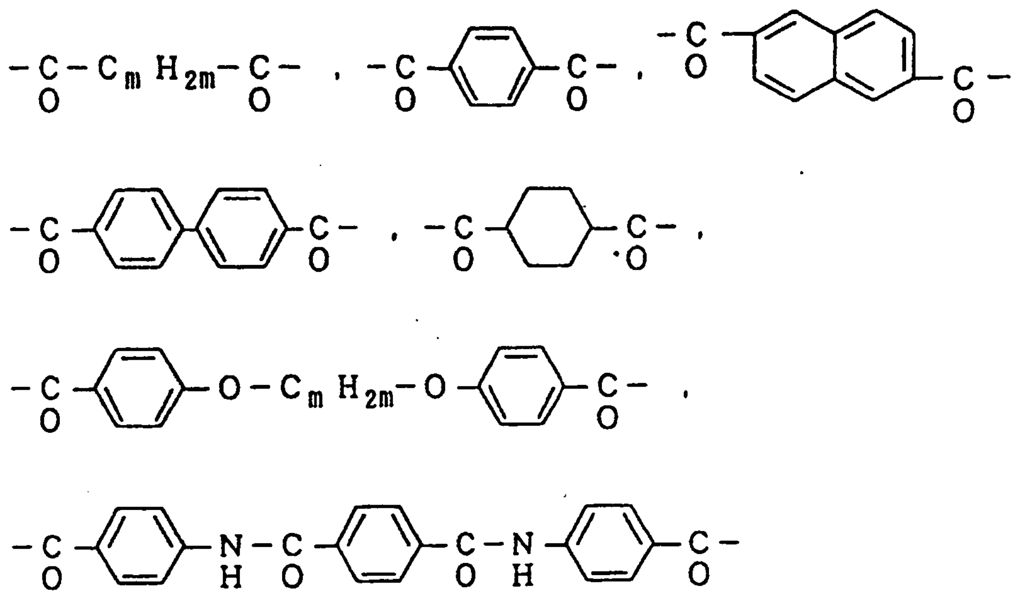
wherein p, q, r, s, t, u, v, w, a, b, c, d, e and f are each an integer of 1-18, preferably 3-14. Q is the following:



etc.

wherein m is an integer of 2-16.

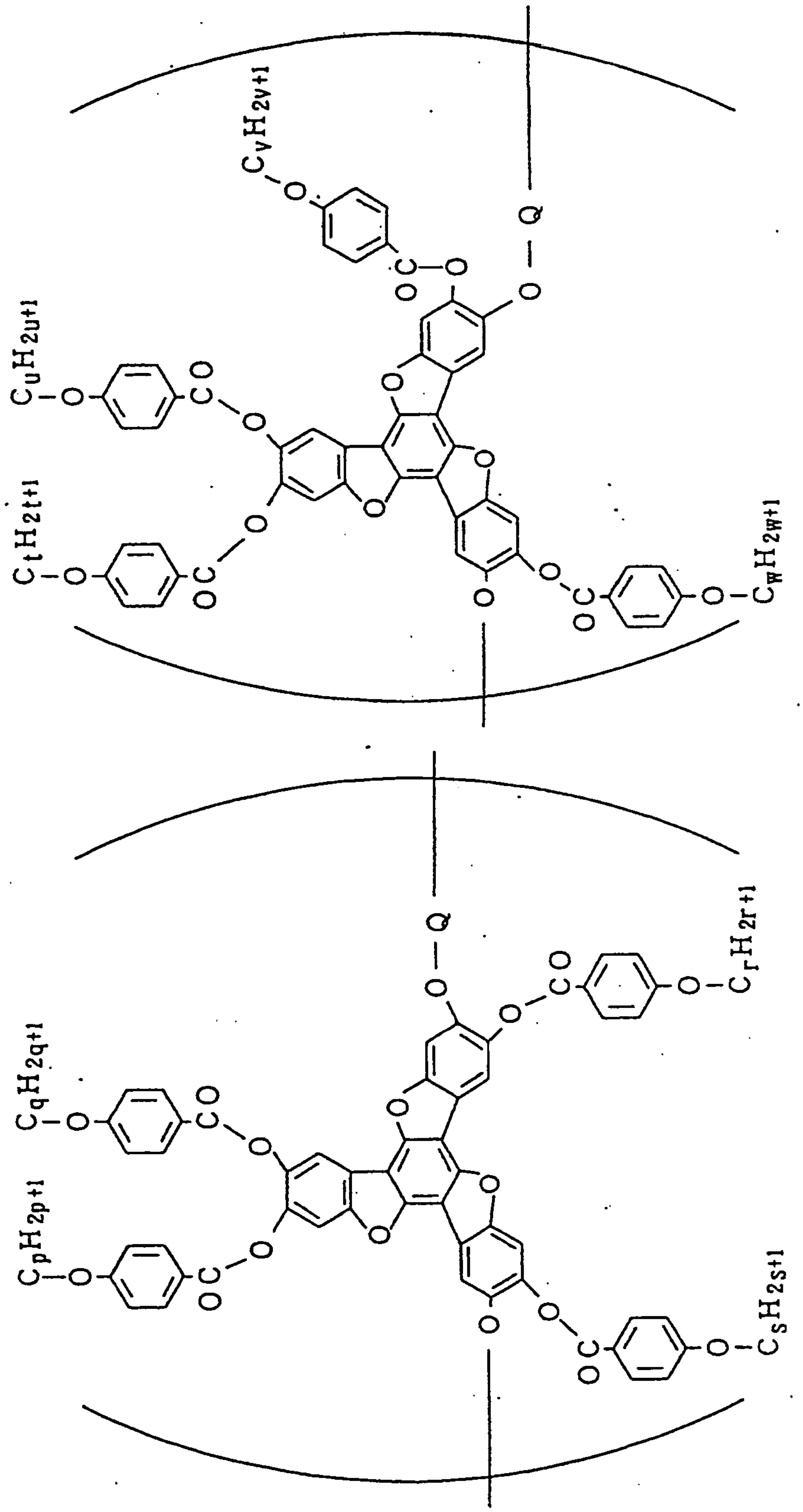
Preferable Q:



etc.

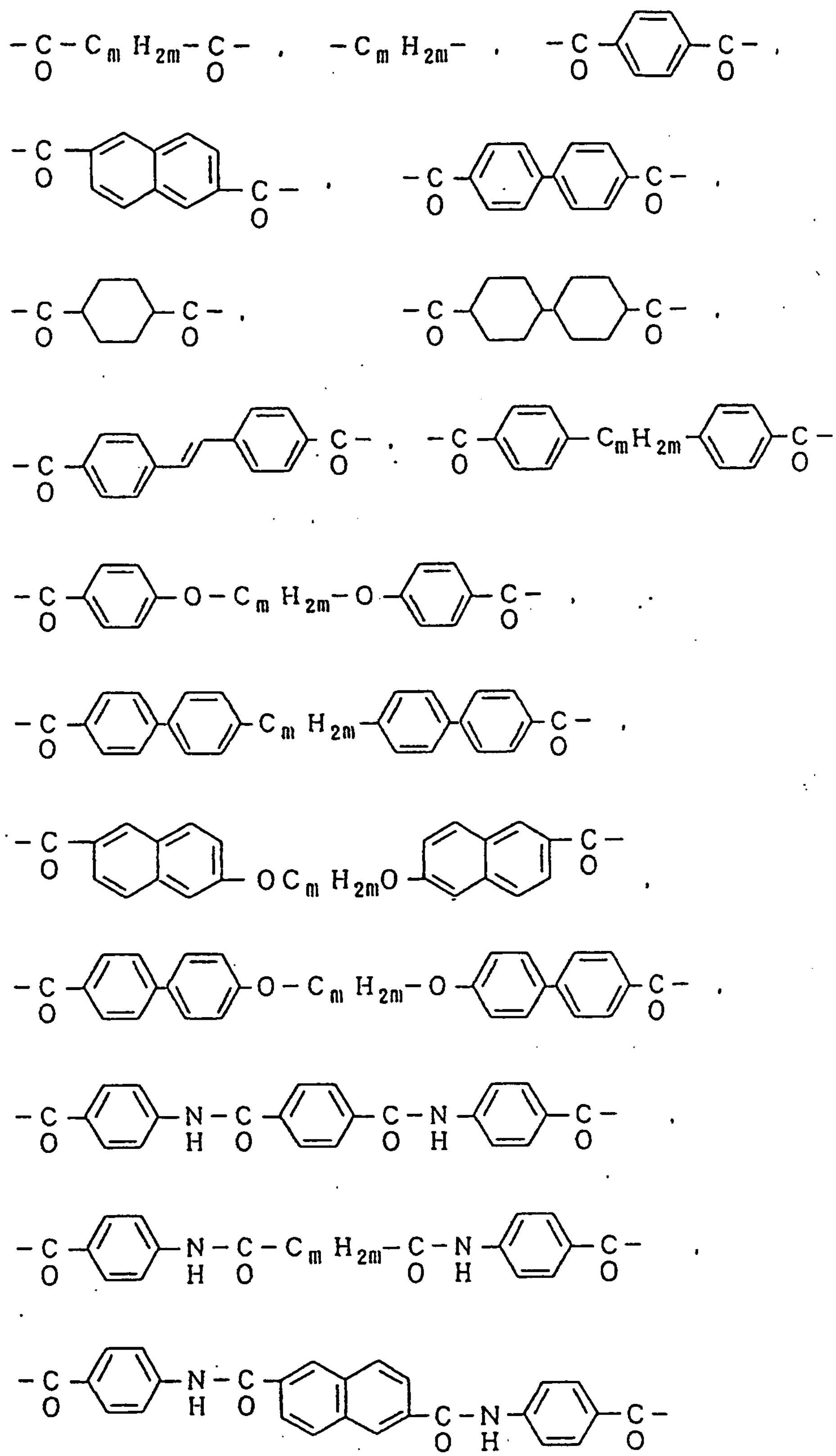
wherein m is an integer of 2-16, preferably 4-12.

Polymer represented by the following:



wherein p, q, r, s, t, u, v and w are each an integer of 1-18, preferably 3-14, and the average molecular weight is 5,000 - 100,000.

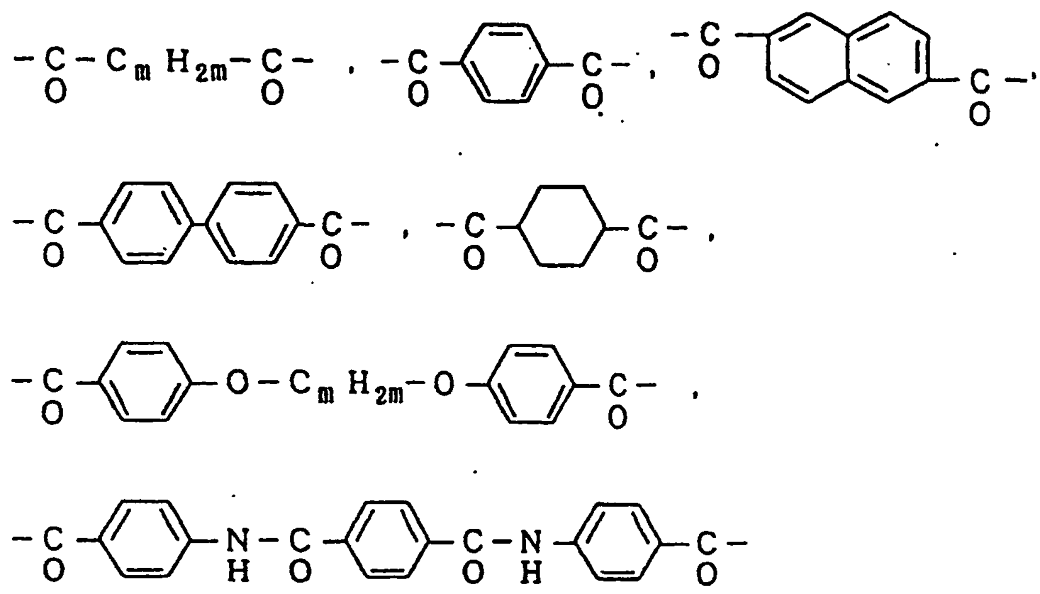
Q is the following:



etc.

wherein m is an integer of 2-16.

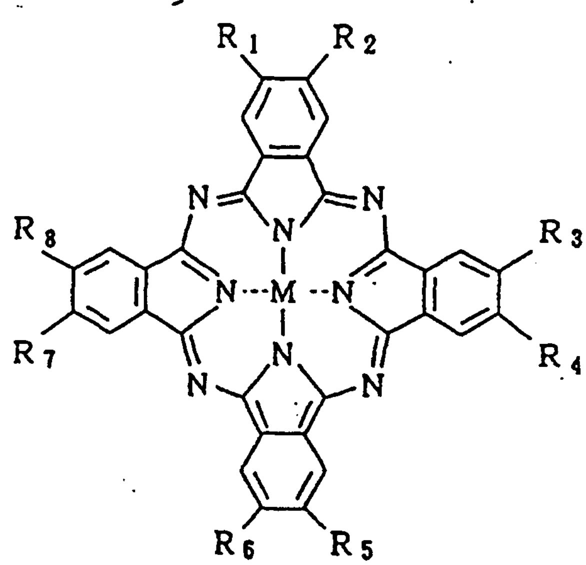
Preferable Q:



etc.

wherein m is an integer of 2-16, preferably 4-12.

[Structural formula 9]

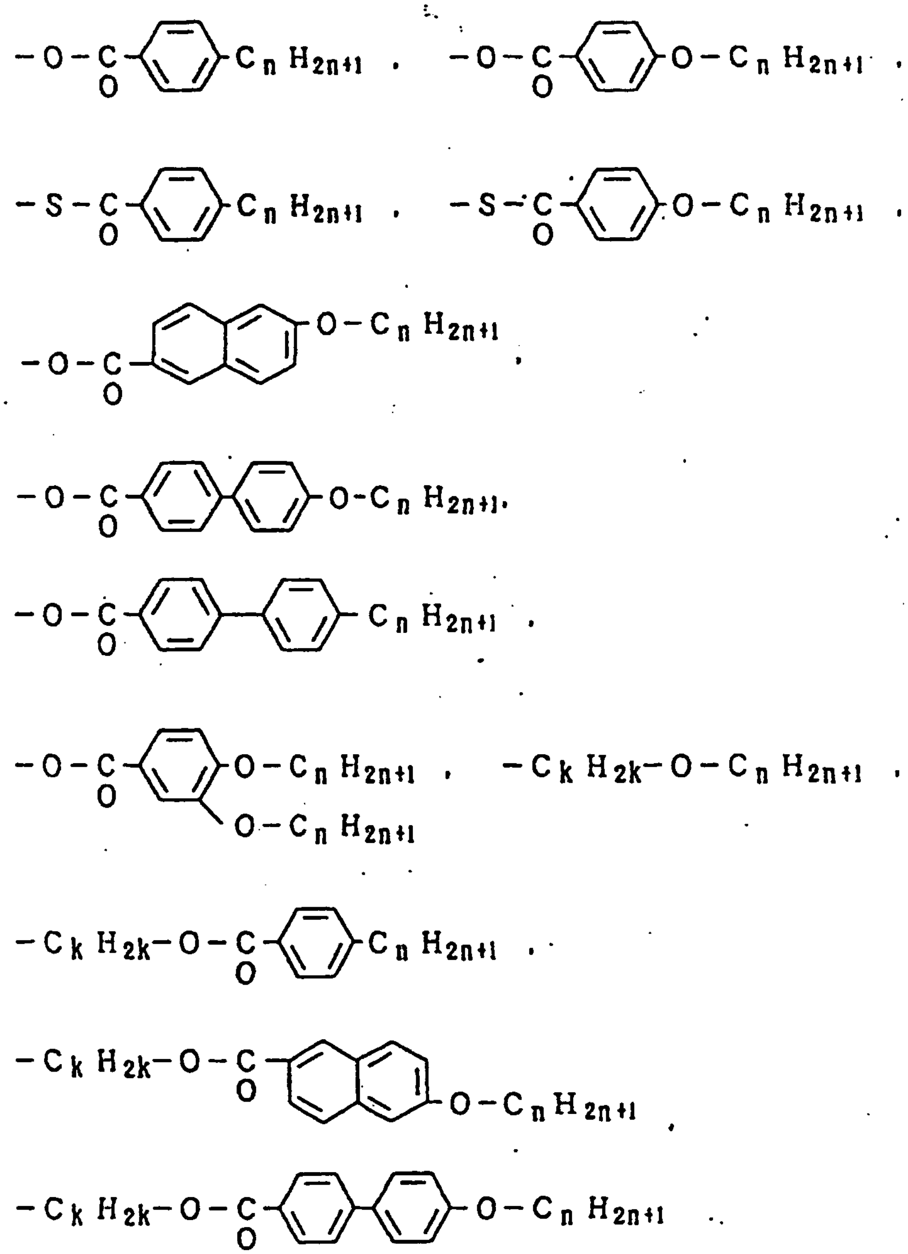


wherein R_1-R_8 are each a monofunctional or bifunctional substituent group selected from the following groups, wherein M represents two protons or a metal such as Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru.

Mono functional substituent groups:

$-C_nH_{2n+1}$, $-O-C_nH_{2n+1}$, $-S-C_nH_{2n+1}$,

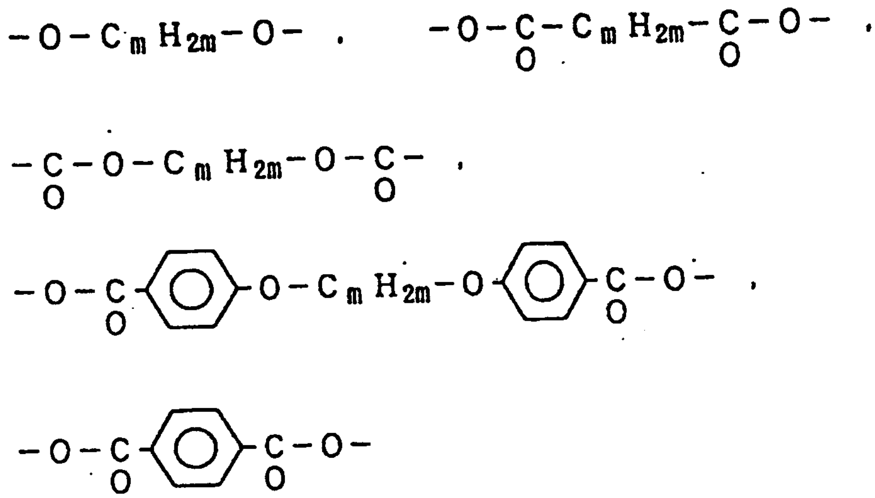
$-\underset{\displaystyle O}{\overset{\|}{C}}-O-C_nH_{2n+1}$, $-O-\underset{\displaystyle O}{\overset{\|}{C}}-C_nH_{2n+1}$,



etc.

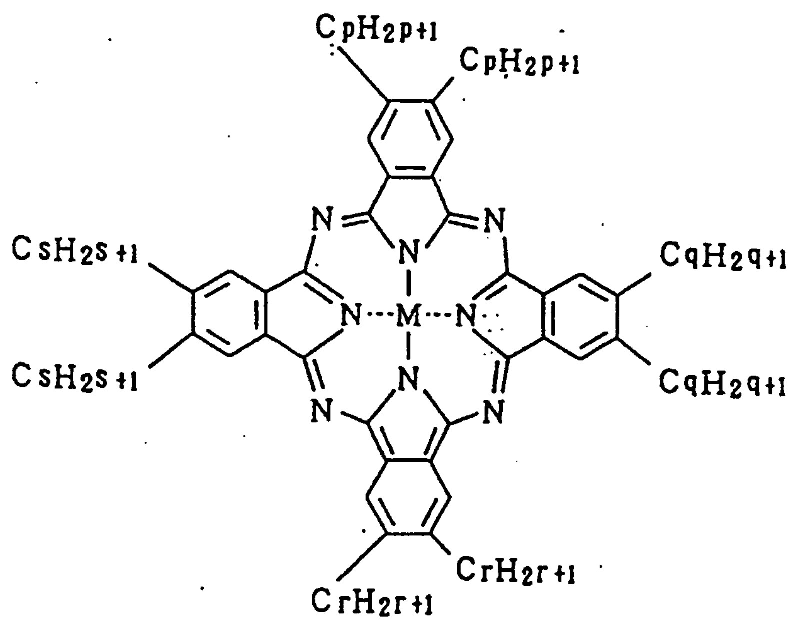
wherein C_nH_{2n+1} is a linear or branched alkyl group, n is an integer of 3-18, preferably 5-14, k is 1, 2 or 3.

Bifunctional substituent groups:

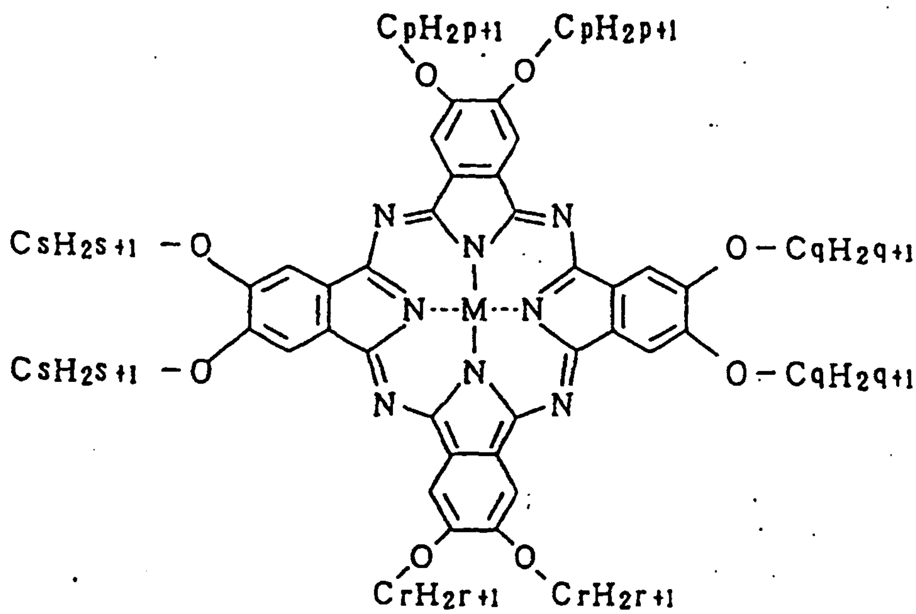


etc.

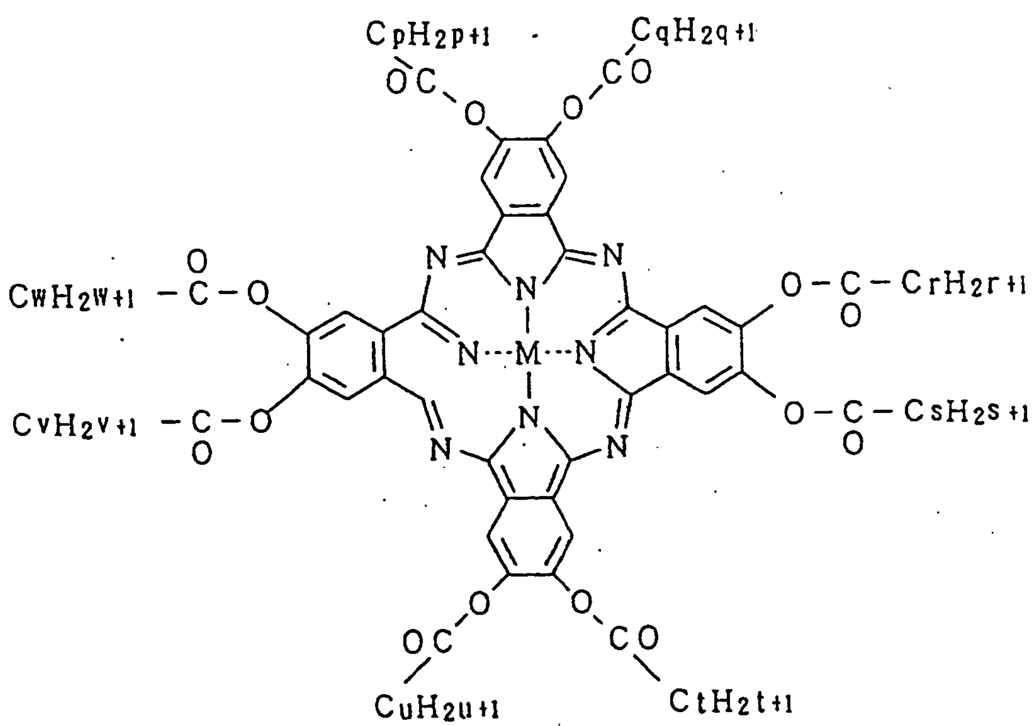
wherein C_mH_{2m} is a linear or branched alkylene chain, and m is an integer of 2-16, preferably 4-12.



wherein M is two protons Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru, preferably two protons Fe, Co, Ni, Zn or Cu. p, q, r and s are each an integer of 3-18, preferably 5-14.



wherein M is two protons Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru, preferably two protons Fe, Co, Ni, Zn or Cu. p, q, r and s are each an integer of 3-18, preferably 5-14.



wherein M is two protons Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru, preferably two protons Fe, Co, Ni, Zn or Cu. p, q, r, s, t, u, v and w are each an integer of 3-18, preferably 5-14.

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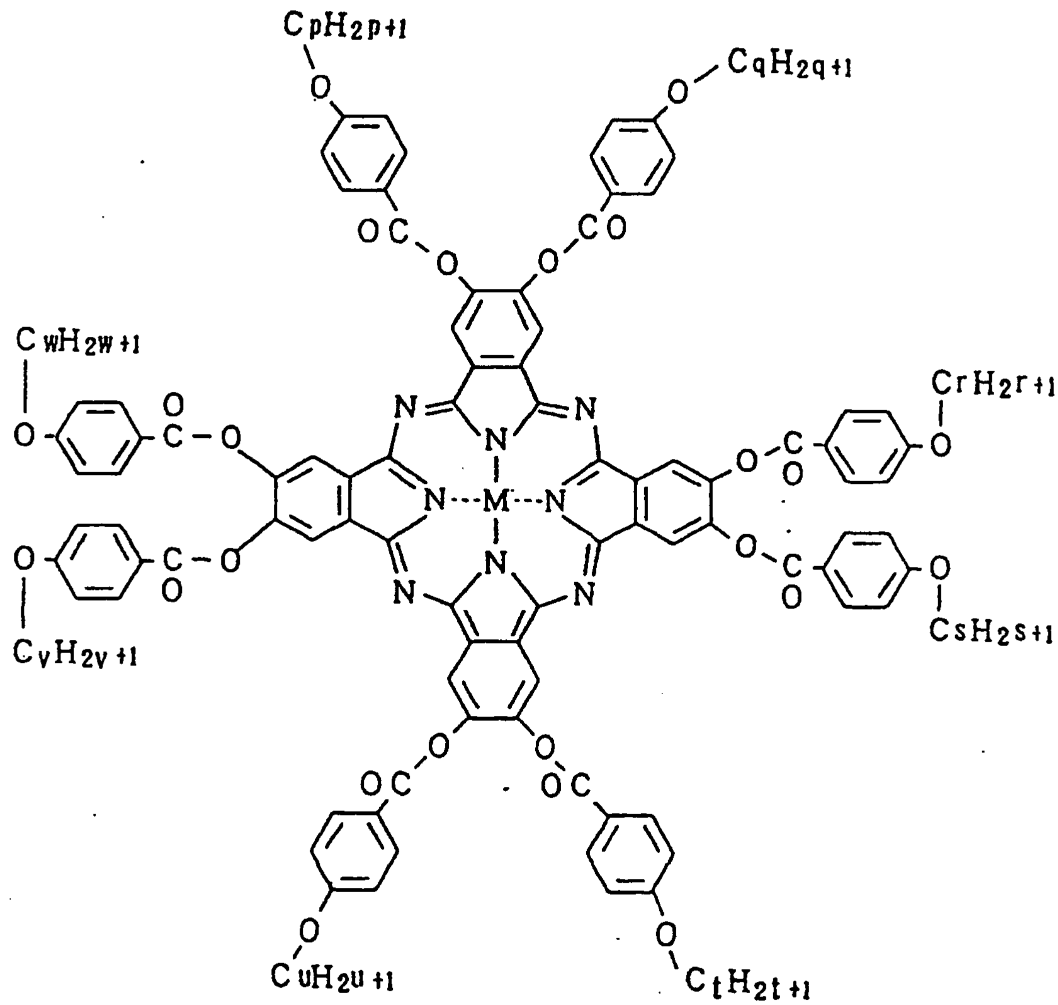
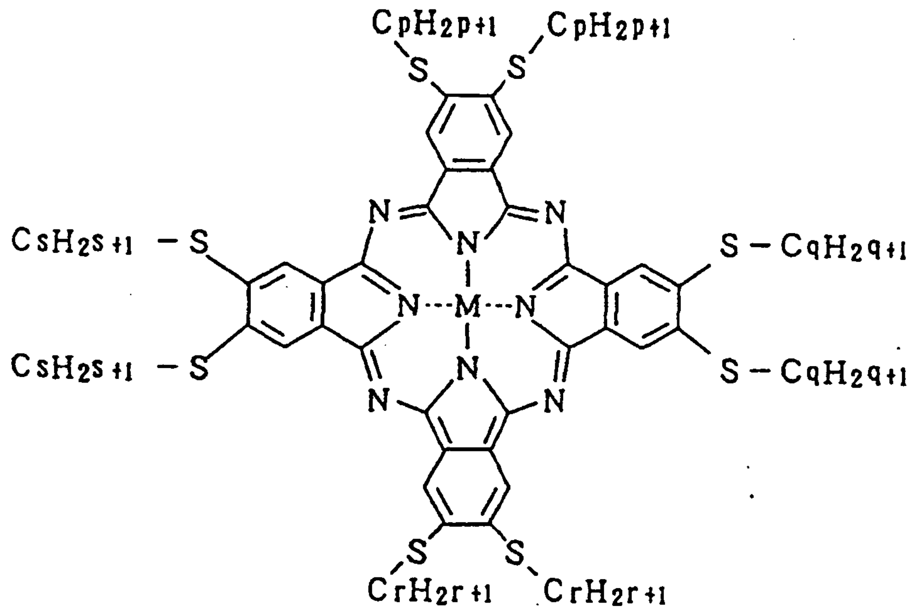


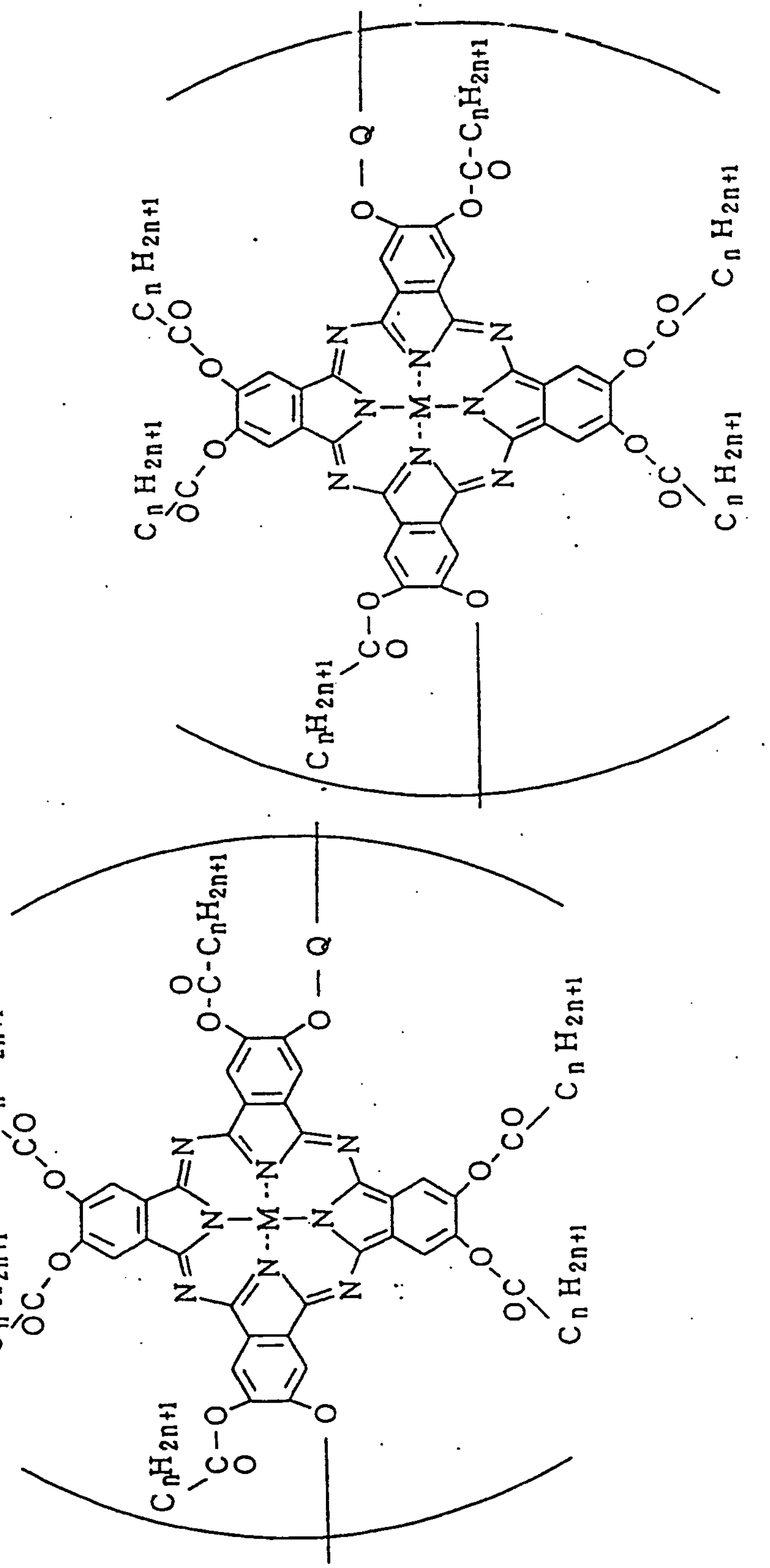
wherein M is two protons Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru, preferably two protons Fe, Co, Ni, Zn or Cu. p, q, r, s, t, u, v and w are each an integer of 3-18, preferably 5-14.

/Cf.



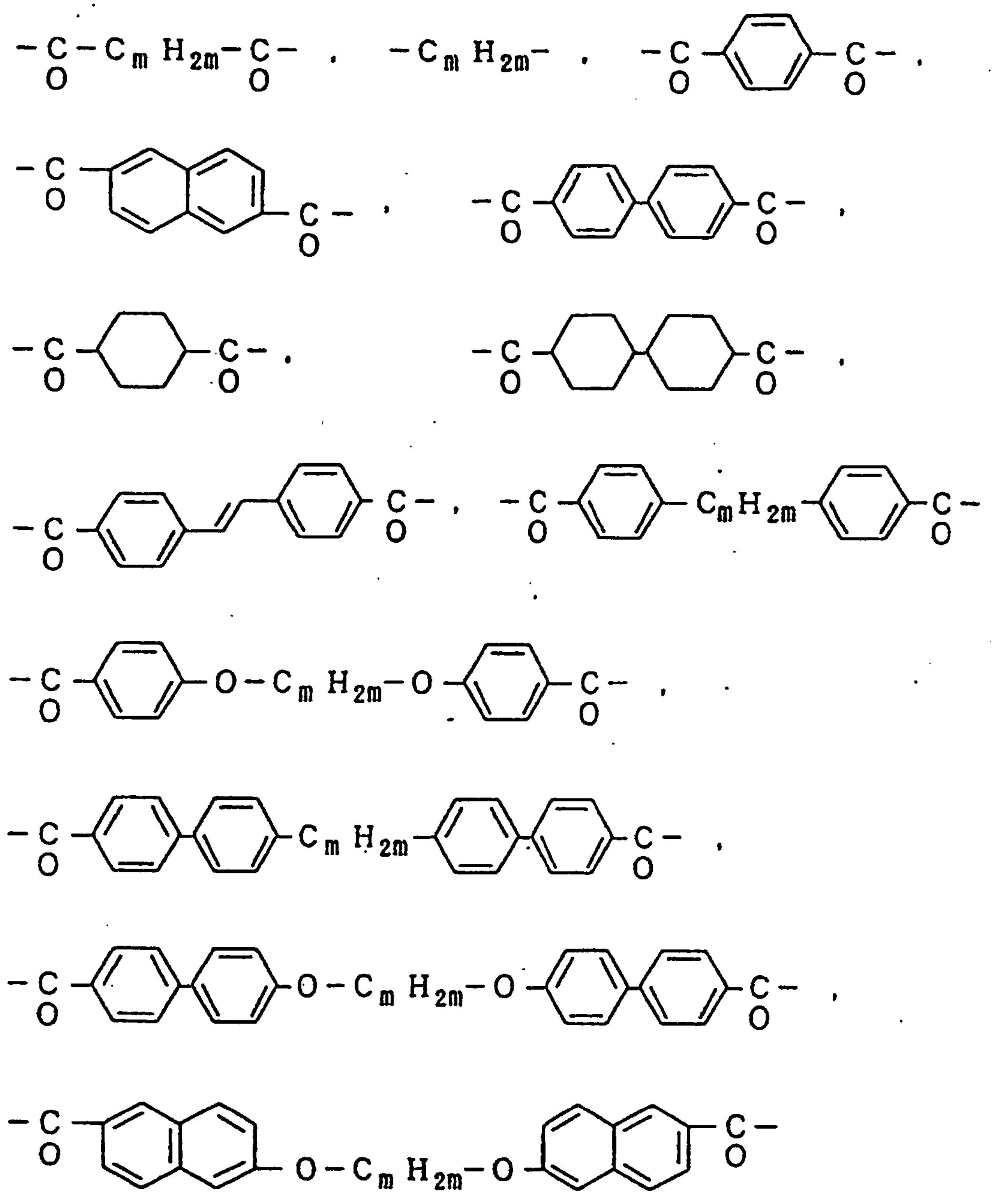
wherein M is two protons Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru, preferably two protons Fe, Co, Ni, Zn or Cu. p, q, r and s are each an integer of 3-18, preferably 5-14.

15



wherein M is two protons Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru, preferably two protons Fe, Co, Ni, Zn or Cu. n is an integer of 3-18, preferably 5-14, m is an integer of 2-16, preferably 4-12, and the average molecular weight is 8,000 - 100,000.

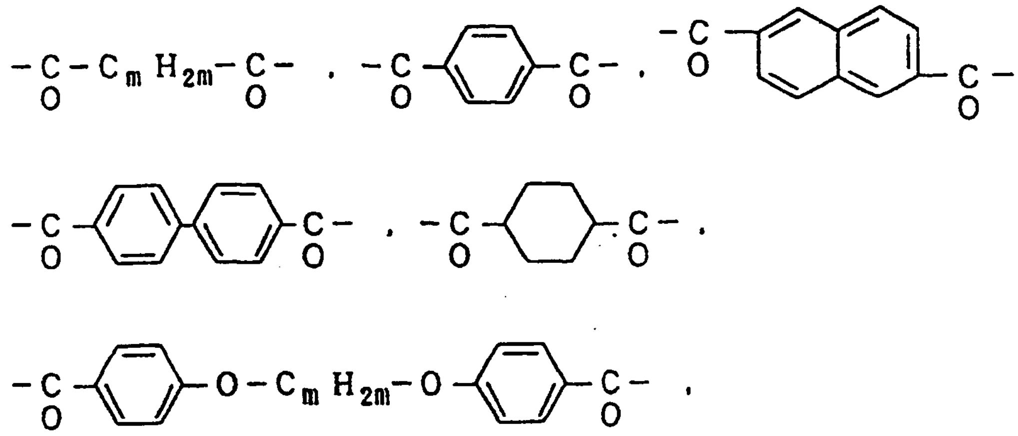
Q is the following:



etc.

wherein m is an integer of 2-18.

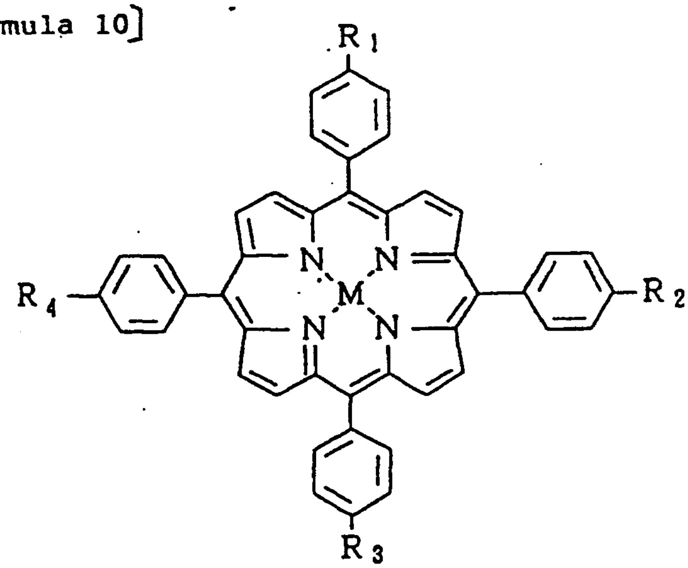
Preferable Q:



etc.

wherein m is an integer of 2-16, preferably 4-12.

[Structural formula 10]

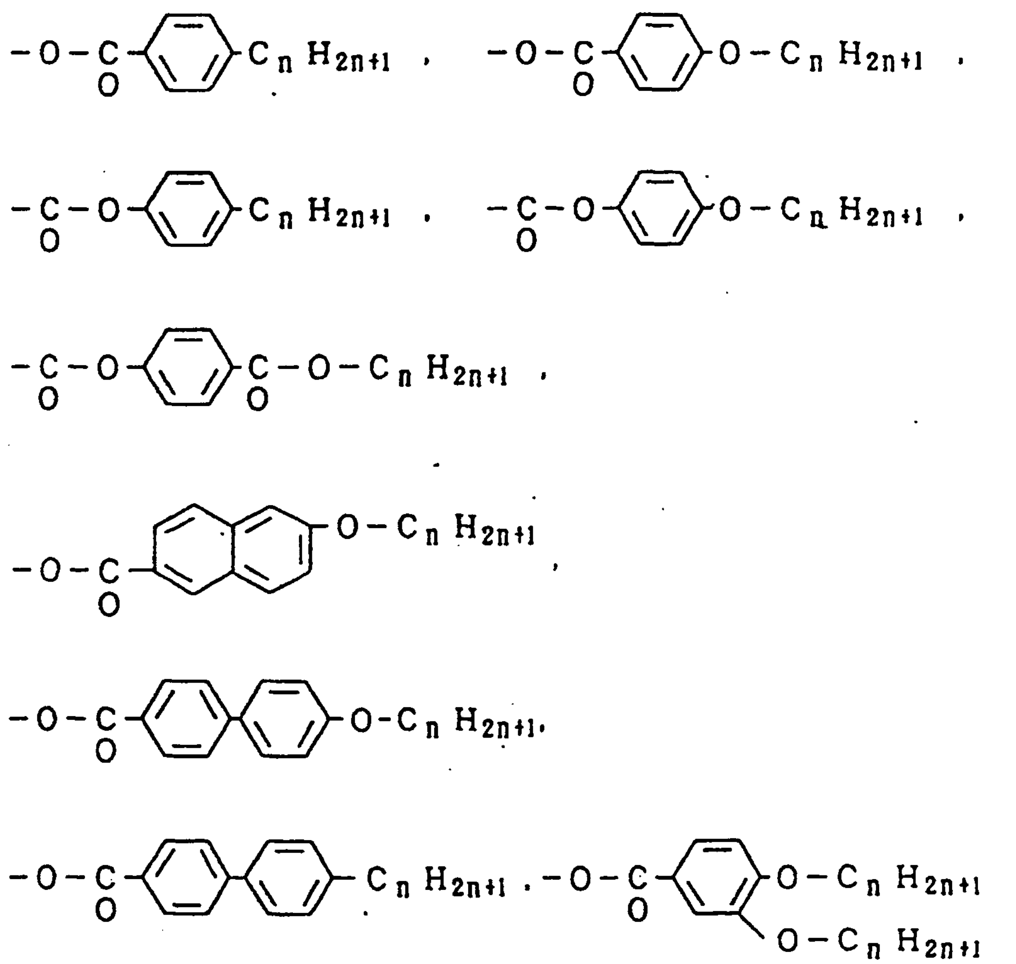


wherein R_1-R_4 are each independently a substituent group selected from the following groups, wherein M is two protons or a metal such as Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru.

Mono functional substituent groups:

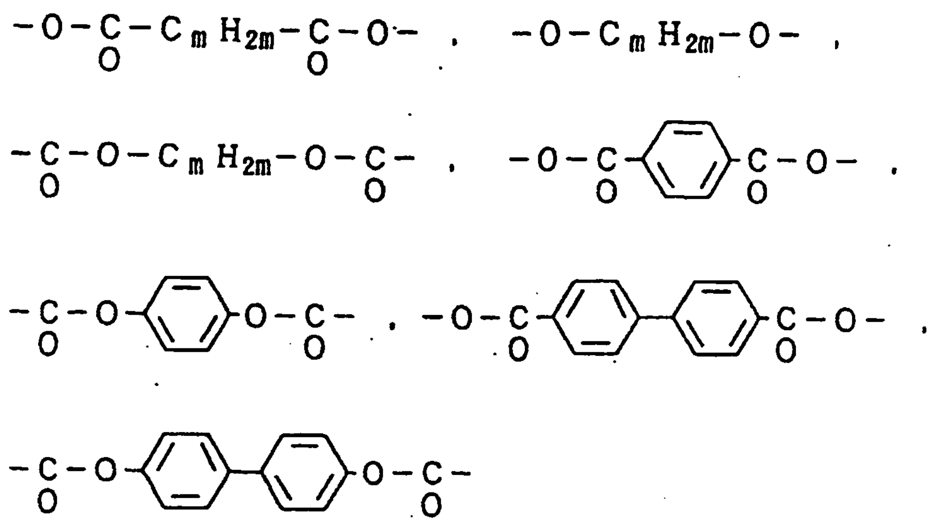
$-C_nH_{2n+1}$, $-O-C_nH_{2n+1}$, $-S-C_nH_{2n+1}$,

$-\underset{\displaystyle O}{C}-O-C_nH_{2n+1}$, $-O-\underset{\displaystyle O}{C}-C_nH_{2n+1}$,



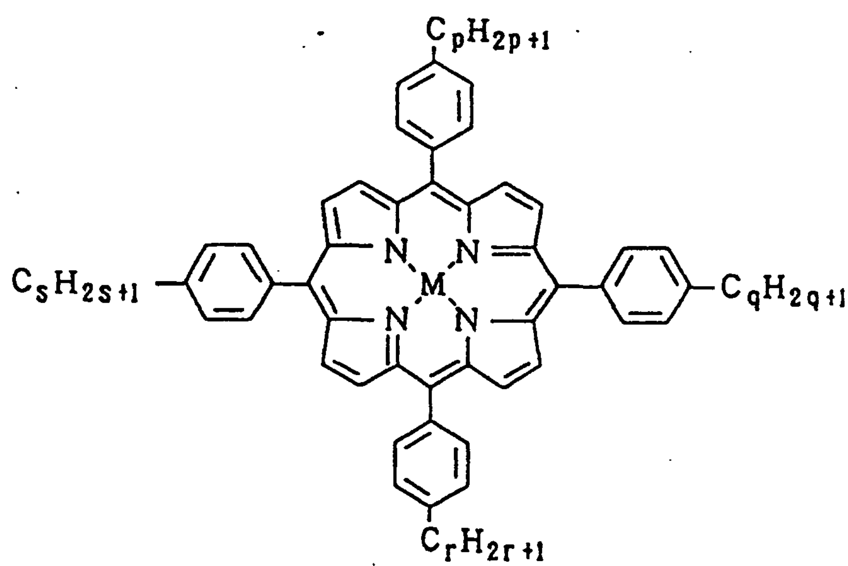
wherein C_nH_{2n+1} is a linear or branched alkyl group, and n is an integer of 3-18, preferably 5-14.

Bifunctional substituent groups:

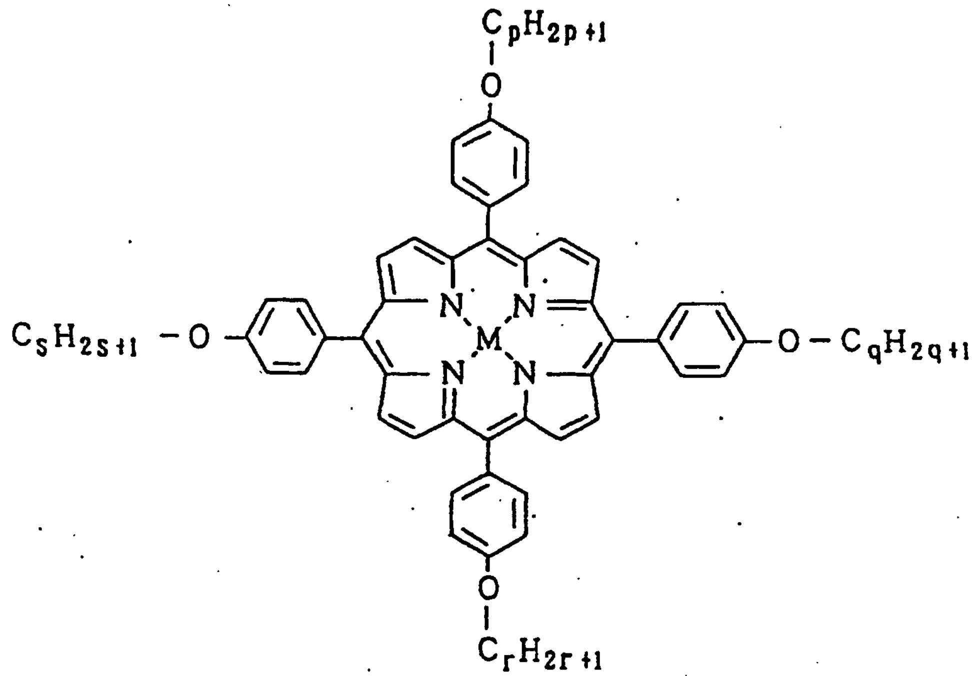


etc.

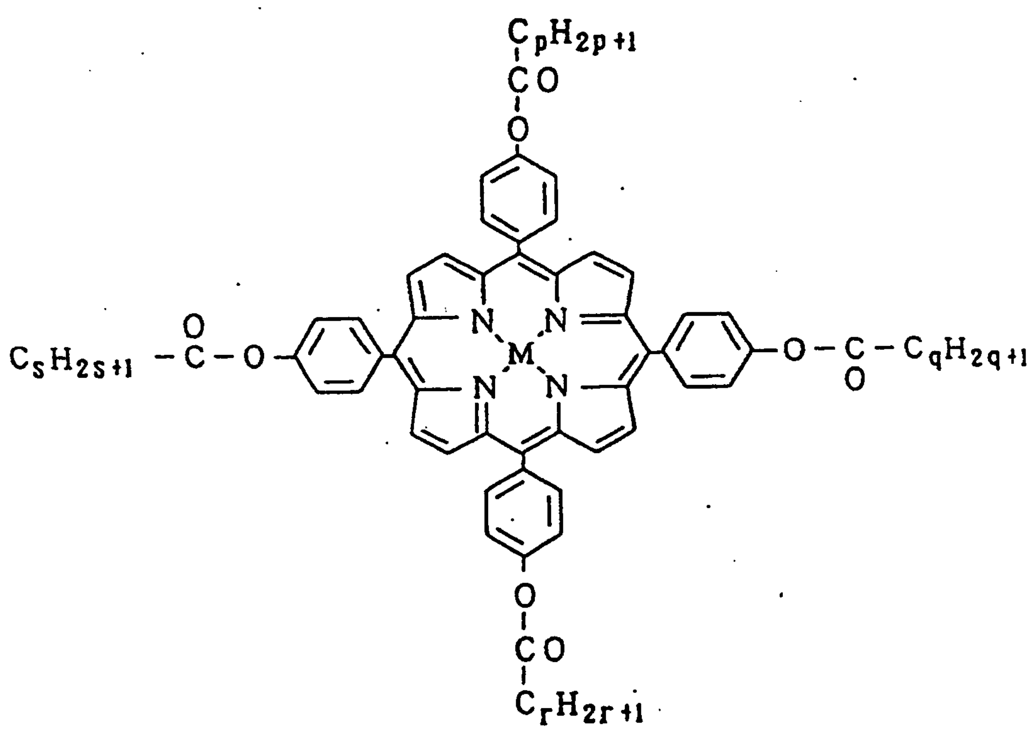
wherein C_mH_{2m} is a linear or branched alkylene chain, and m is an integer of 2-16, preferably 4-12.



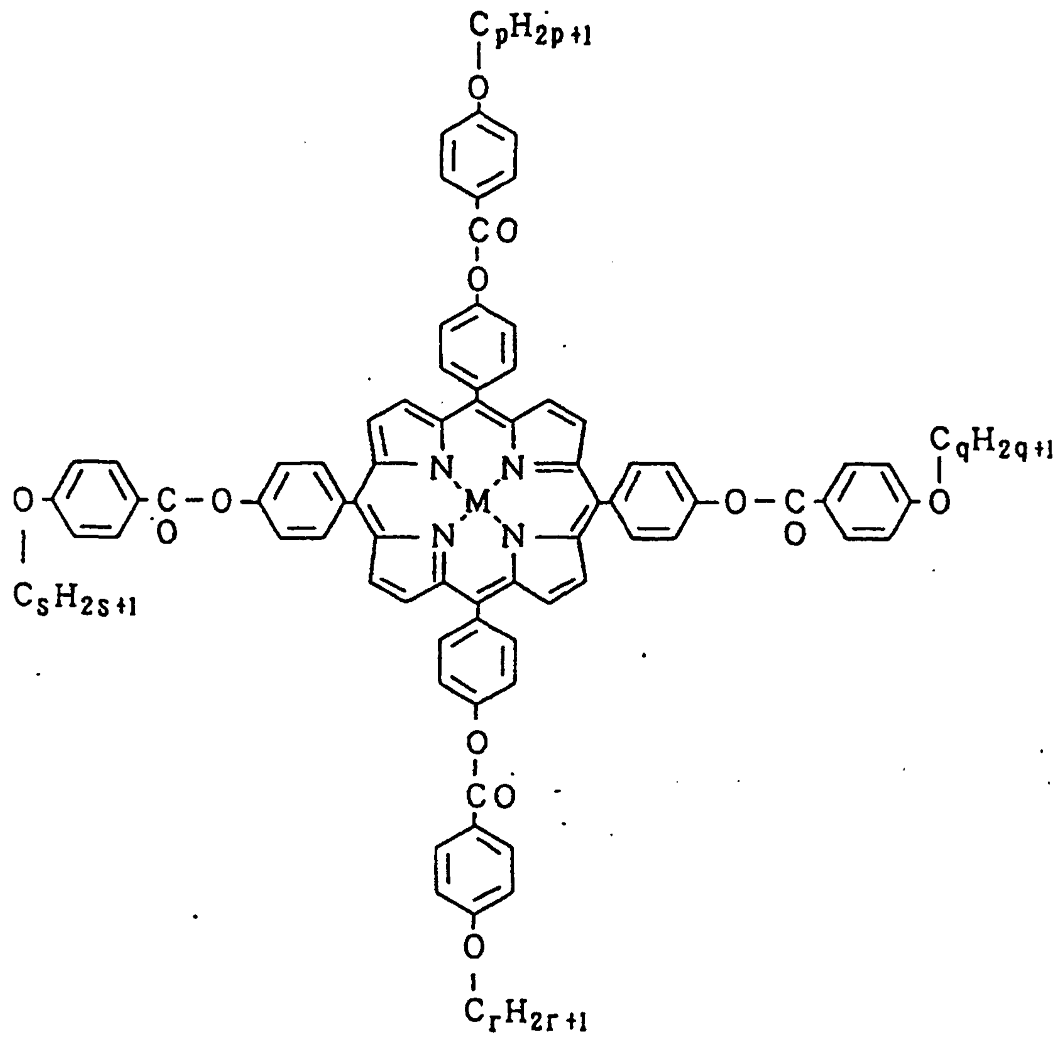
wherein M is two protons Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru, preferably two protons Fe, Co, Ni, Zn or Cu. p, q, r and s are each an integer of 3-18, preferably 5-14.



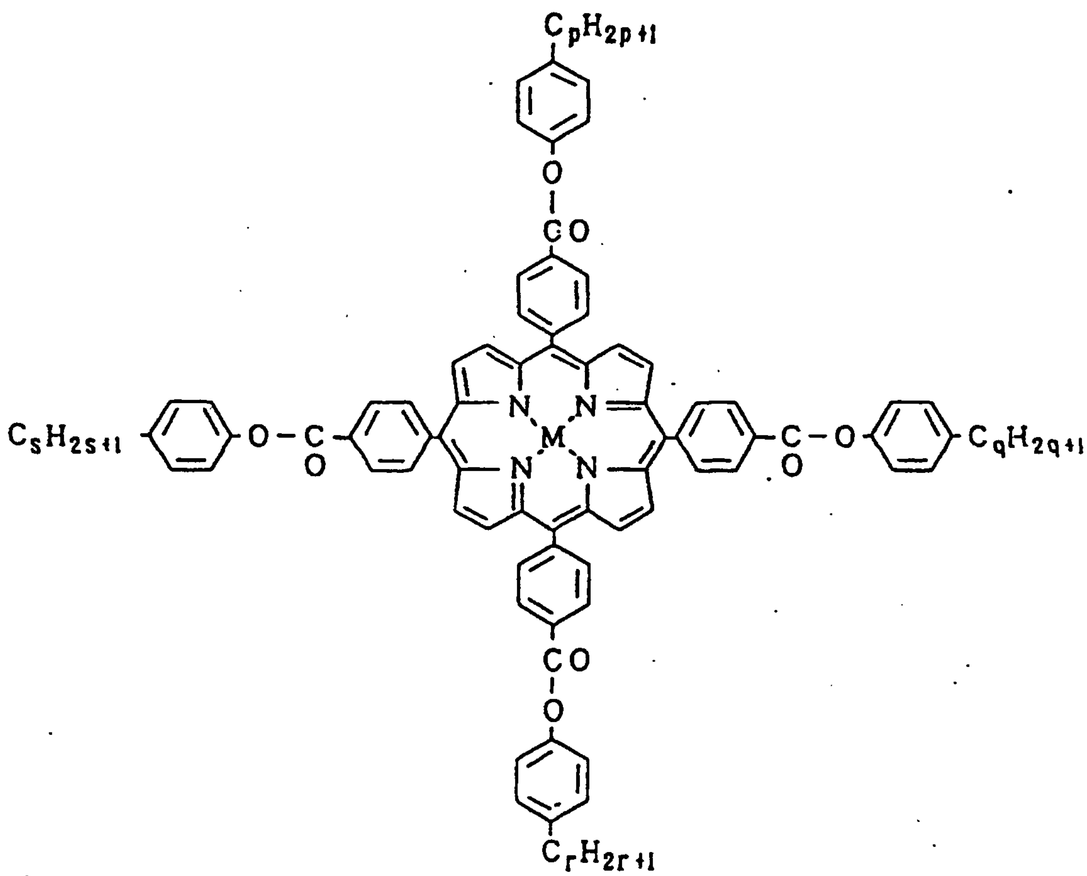
wherein M is two protons Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru, preferably two protons Fe, Co, Ni, Zn or Cu. p, q, r and s are each an integer of 3-18, preferably 5-14.



wherein M is two protons Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru, preferably two protons Fe, Co, Ni, Zn or Cu. p, q, r and s are each an integer of 3-18, preferably 5-14.



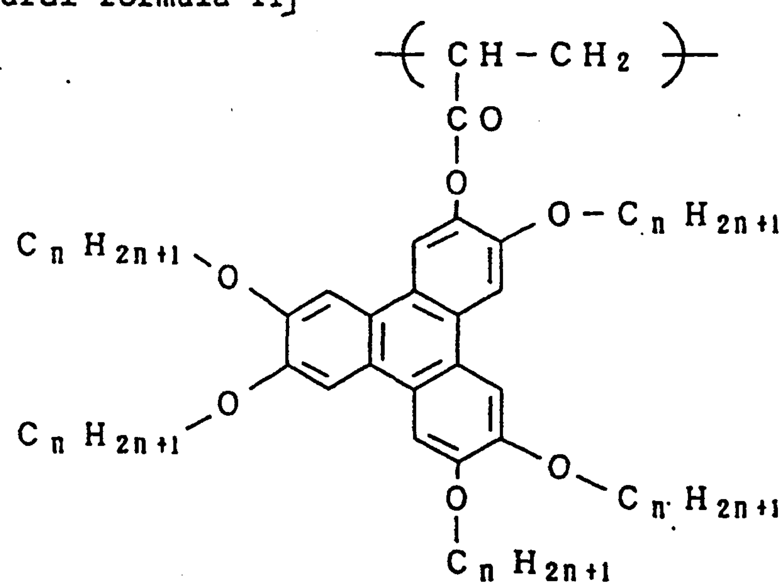
wherein M is two protons Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru, preferably two protons Fe, Co, Ni, Zn or Cu. p, q, r and s are each an integer of 3-18, preferably 5-14.



wherein M is two protons Mg, Fe, Co, Ni, Mn, Zn, Cu, Pb, Pd, Cd, Rh or Ru, preferably two protons Fe, Cc, Ni, Zn or Cu. p, q, r and s are each an integer of 3-18, preferably 5-14.

Also, polymers such as polyacrylates or polysiloxanes having a compound having the above mentioned structural formula at the side chain are preferably used.
Examples thereof are as follows:

[Structural formula 11]



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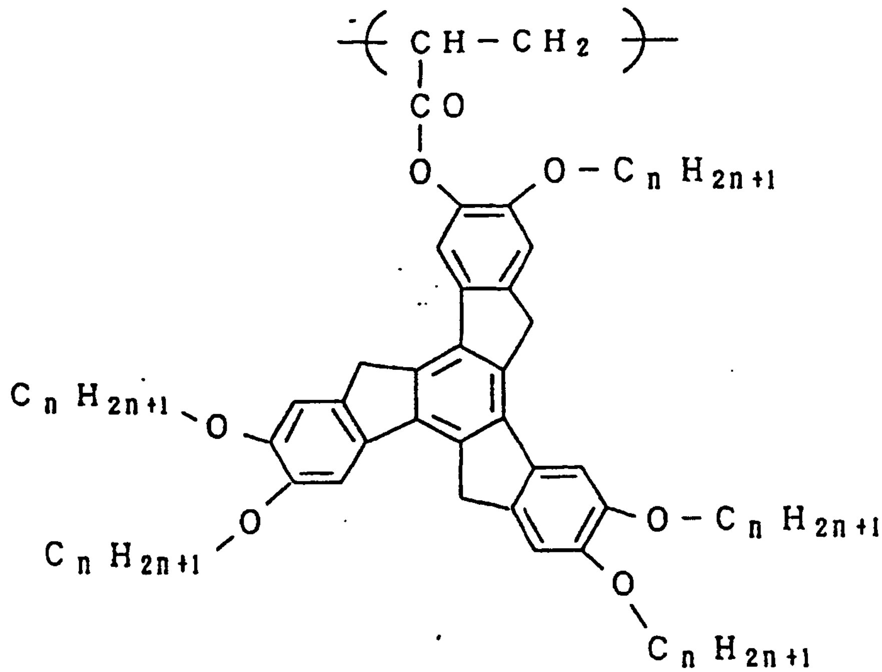
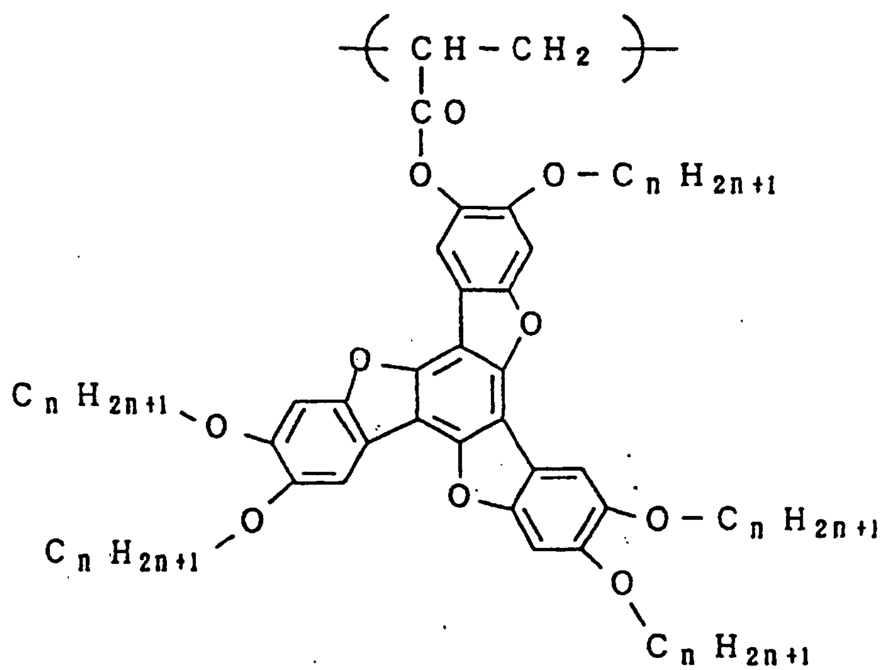
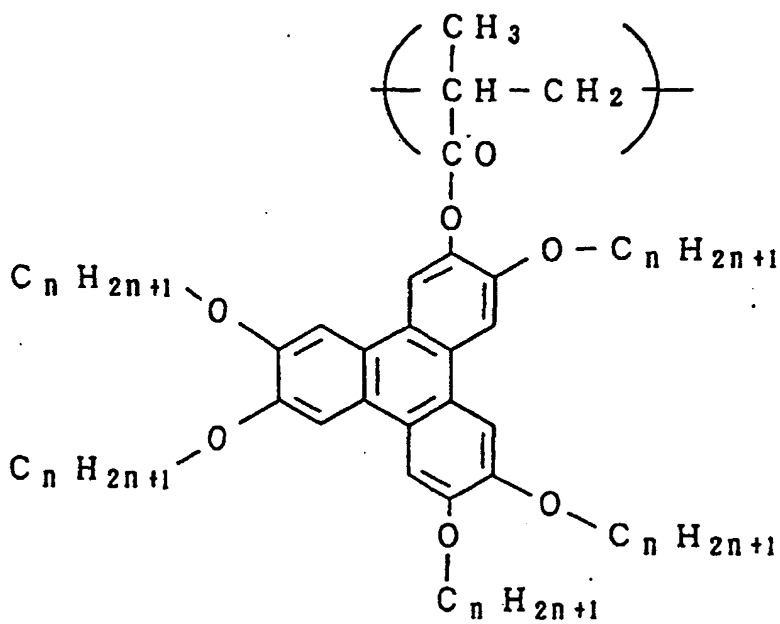
wherein n is an integer of 1-18, preferably 3-14.



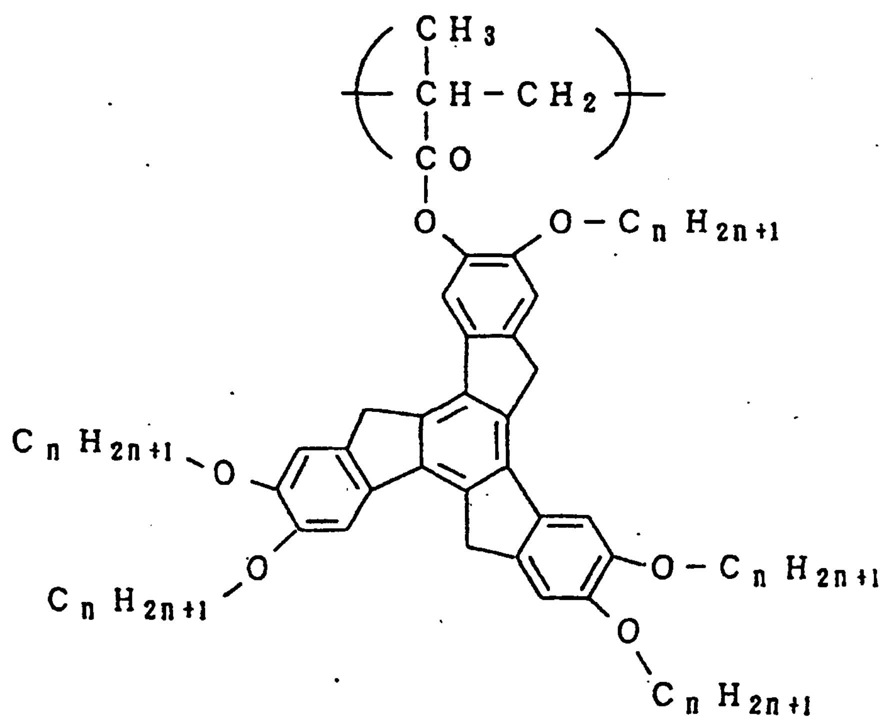
wherein n is an integer of 1-18, preferably 3-14.



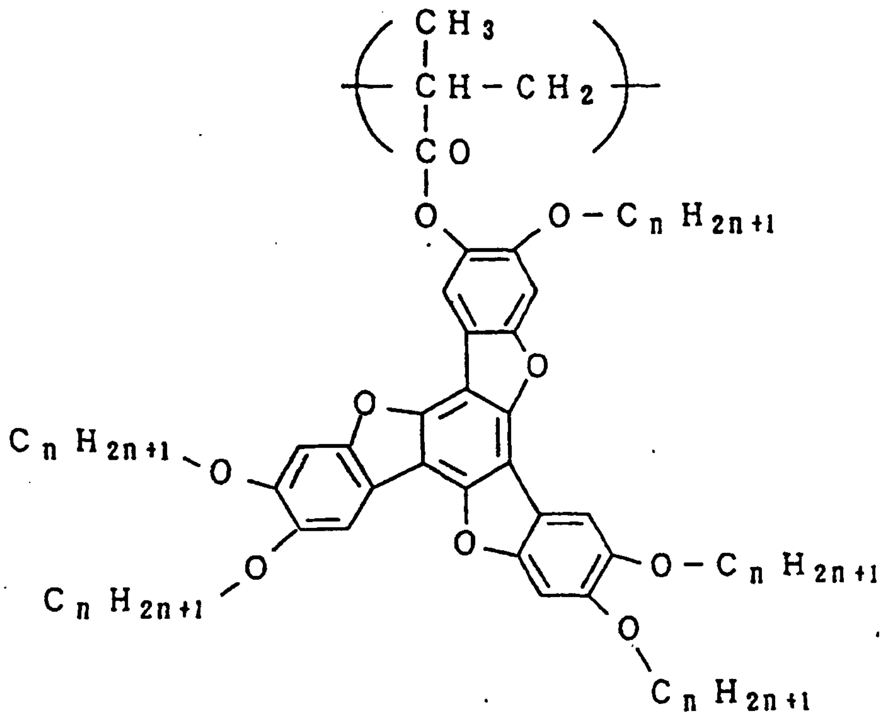
wherein n is an integer of 1-18, preferably 3-14.



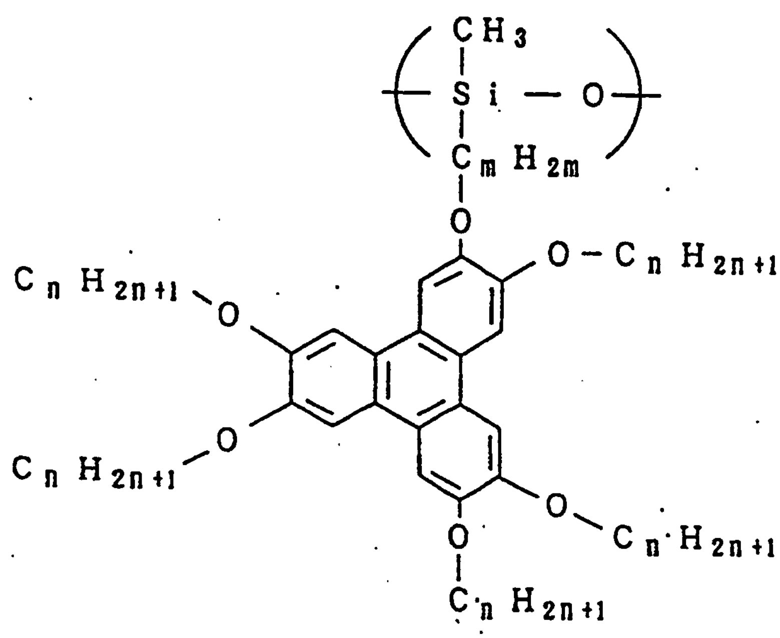
wherein n is an integer of 1-18, preferably 3-14.



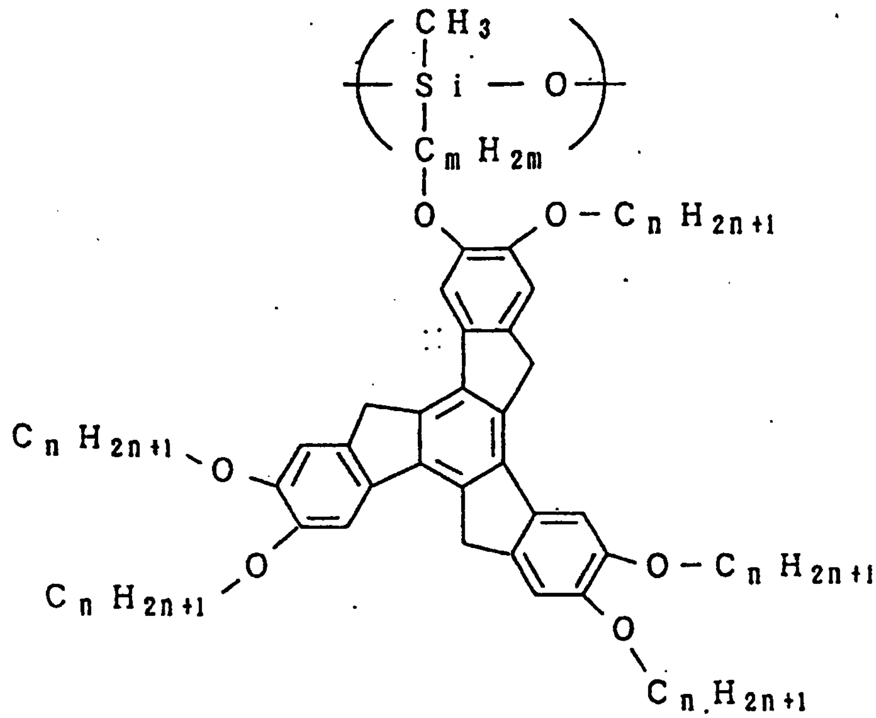
wherein n is an integer of 1-18, preferably 3-14.



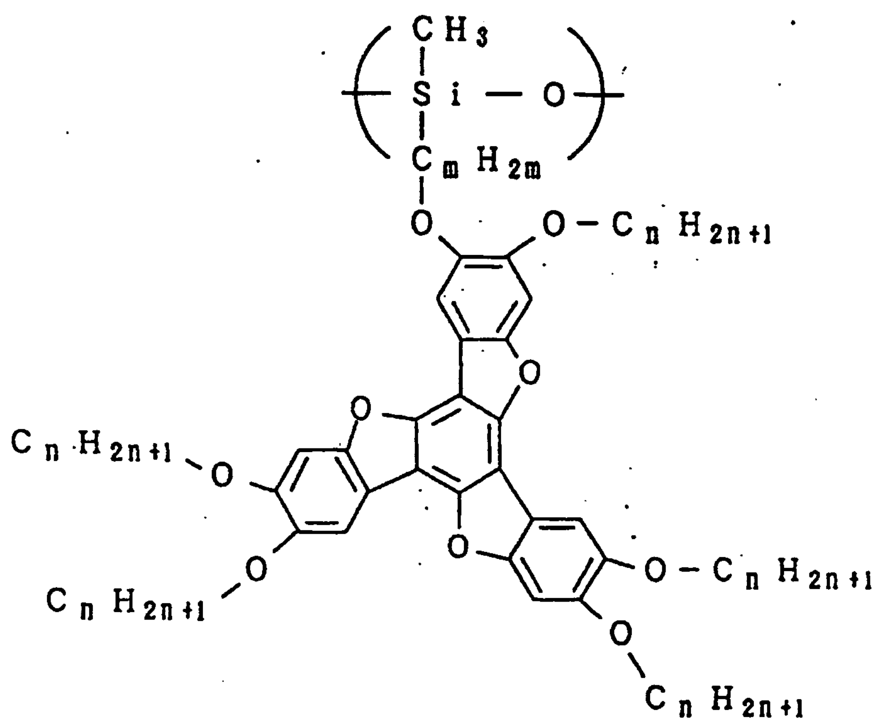
wherein n is an integer of 1-18, preferably 3-14.



wherein n is an integer of 2-18, preferably 3-14, m is an integer of 2-16, preferably 4-12.



wherein n is an integer of 1-18, preferably 3-14, m is an integer of 2-16, preferably 4-12.



wherein n is an integer of 1-18, preferably 3-14, m is an integer of 2-16, preferably 4-12.

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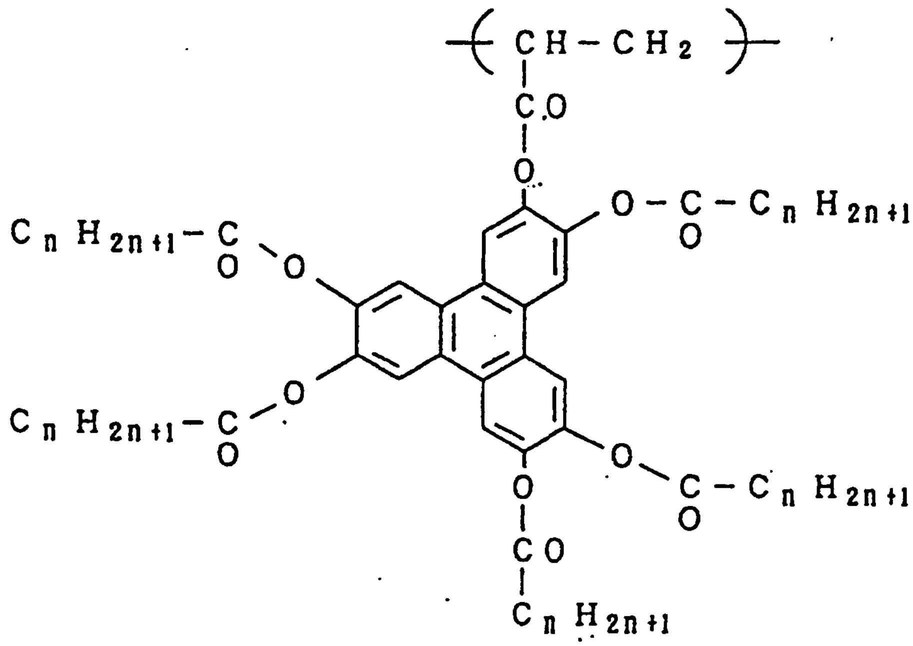
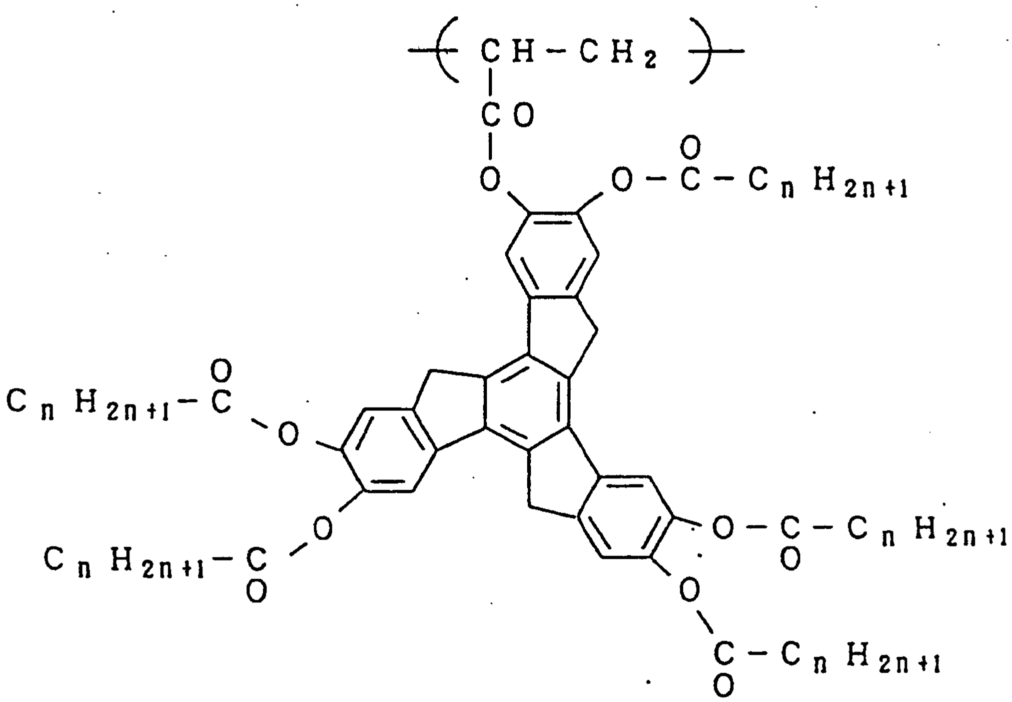
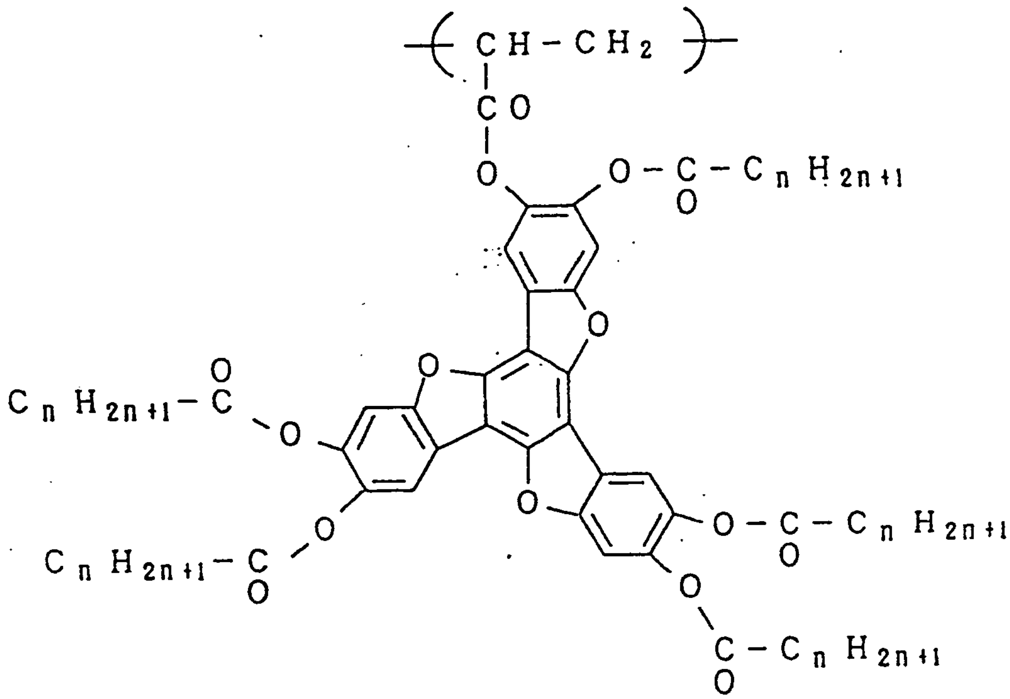


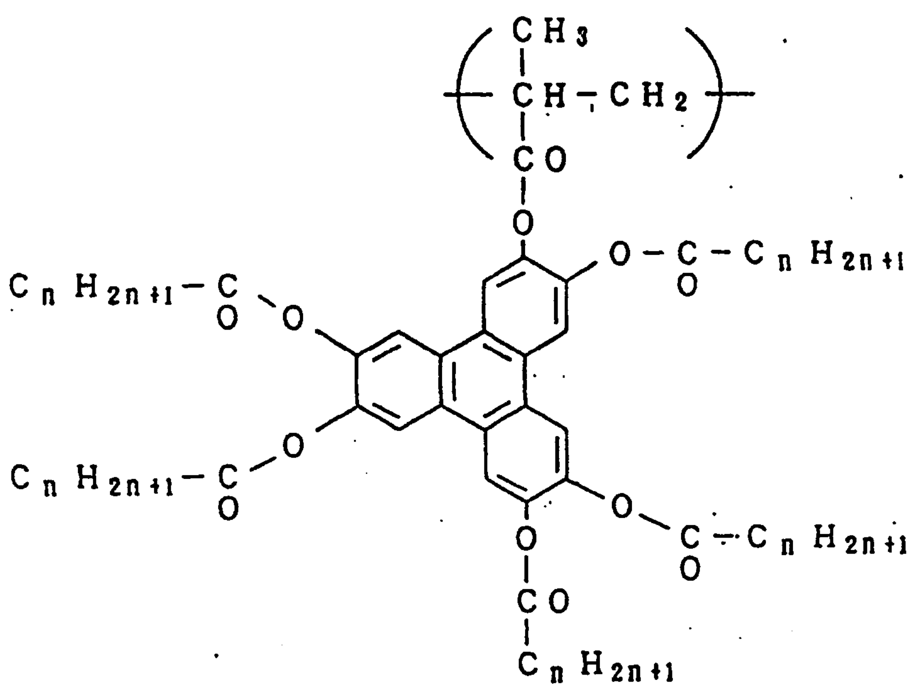
wherein n is an integer of 1-18, preferably 3-14.



wherein n is an integer of 1-18, preferably 3-14.



wherein n is an integer of 1-18, preferably 3-14.



wherein n is an integer of 1-18, preferably 3-14.

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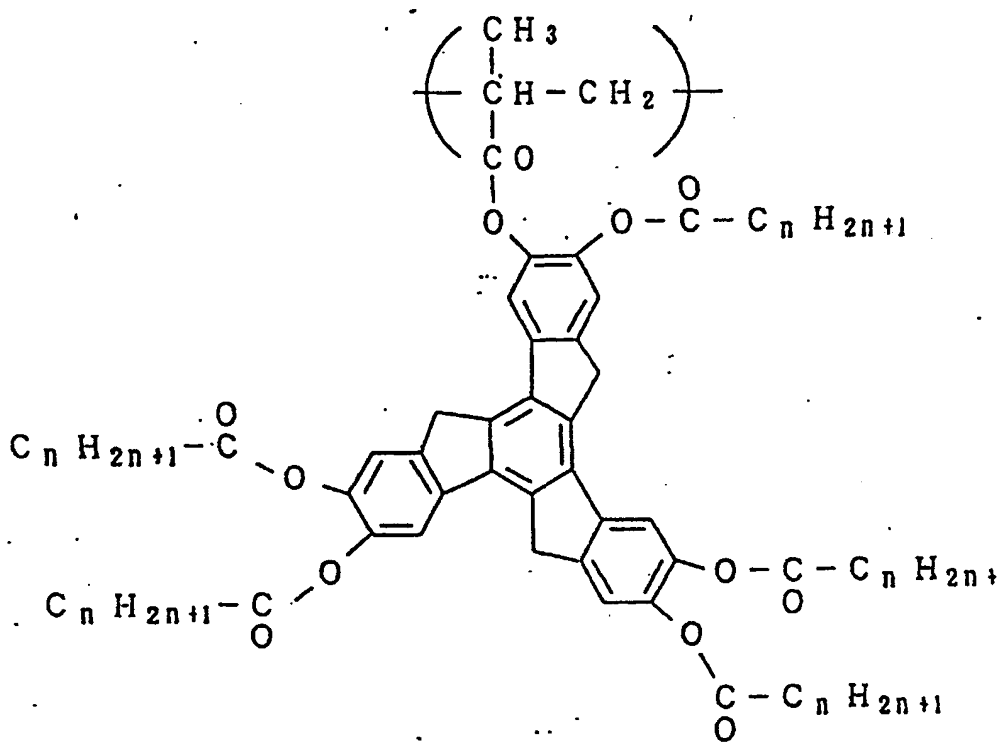
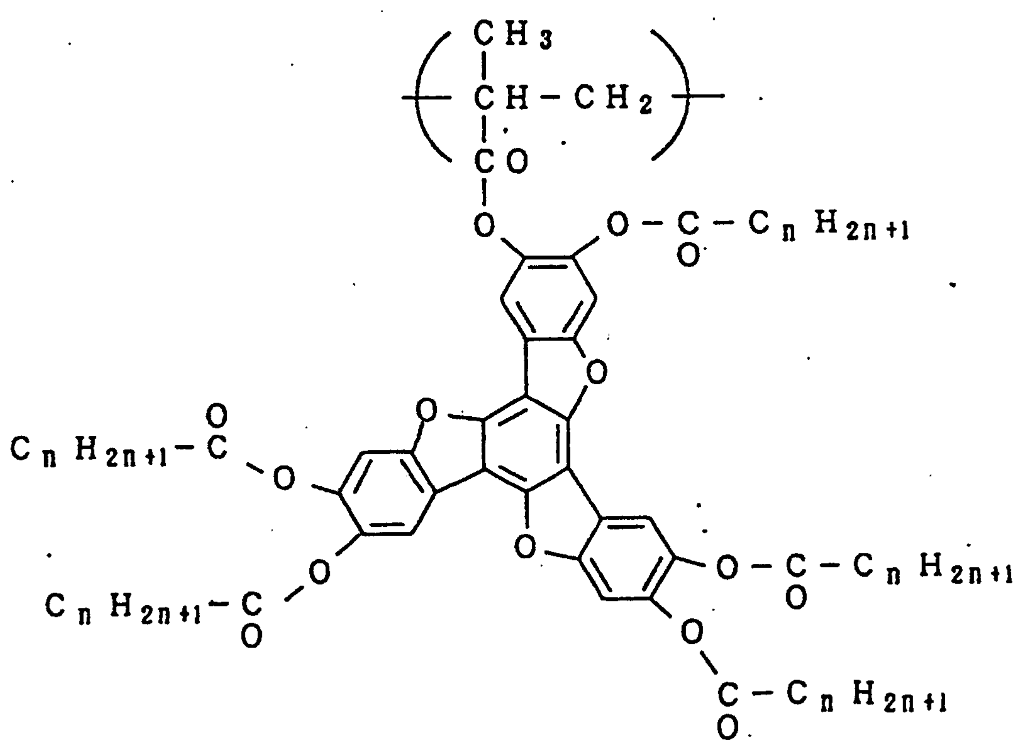
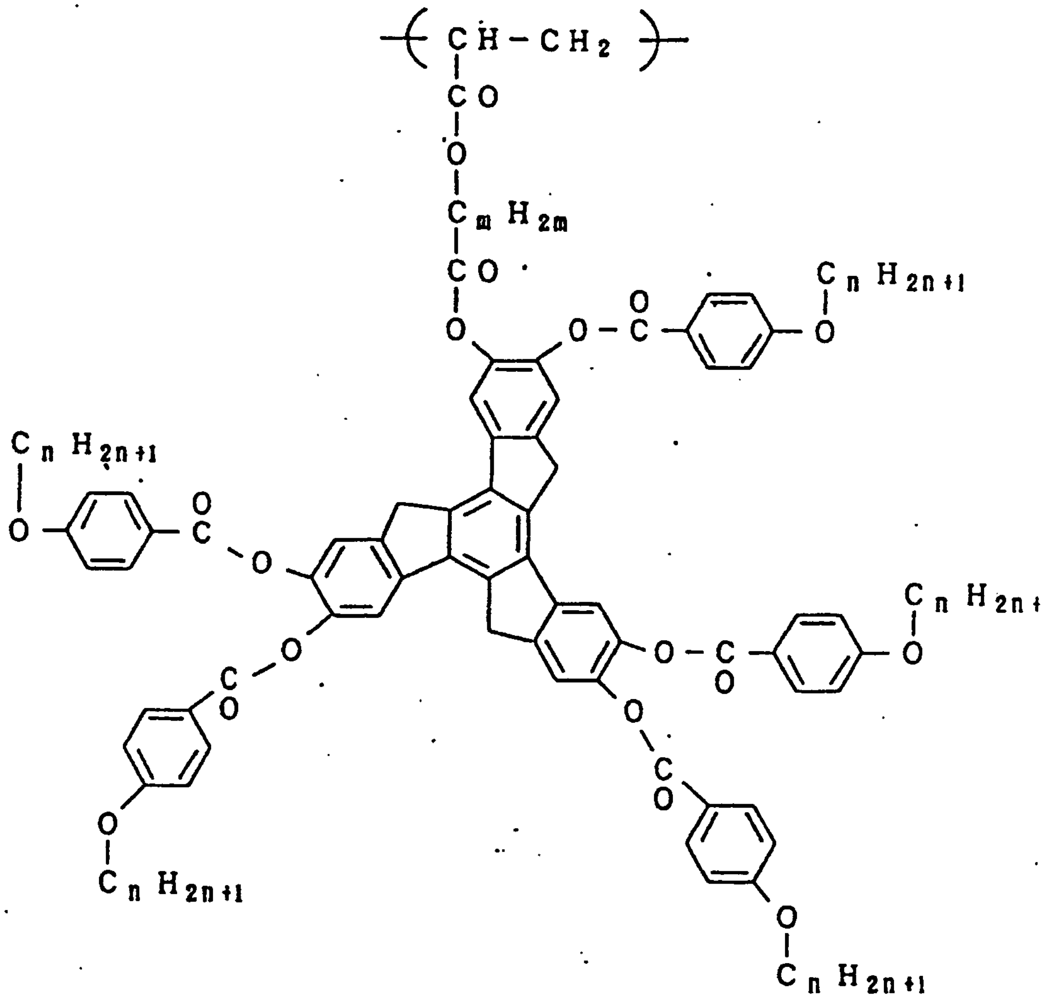


wherein n is an integer of 1-18, preferably 3-14.



wherein n is an integer of 1-18, preferably 3-14.



wherein n is an integer of 1-18, preferably 3-14. m is an integer of 2-16, preferably 4-12.

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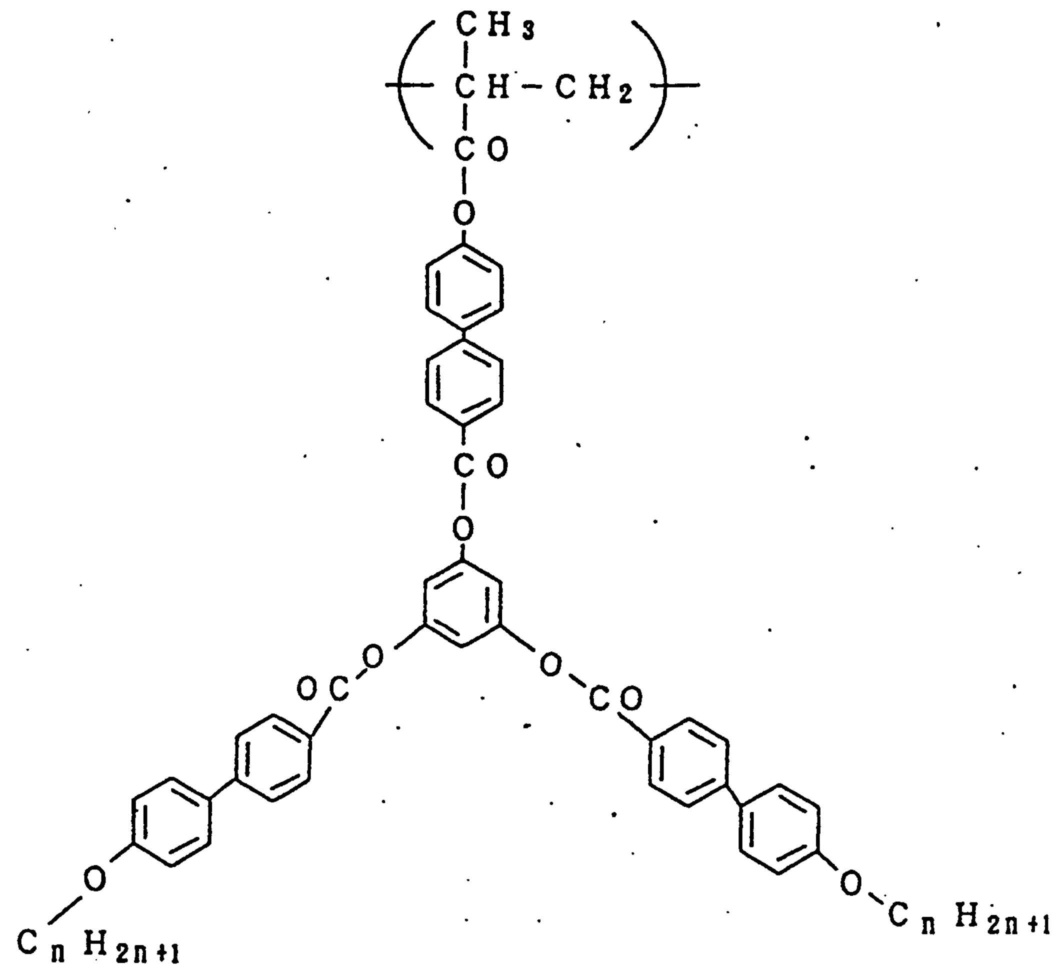
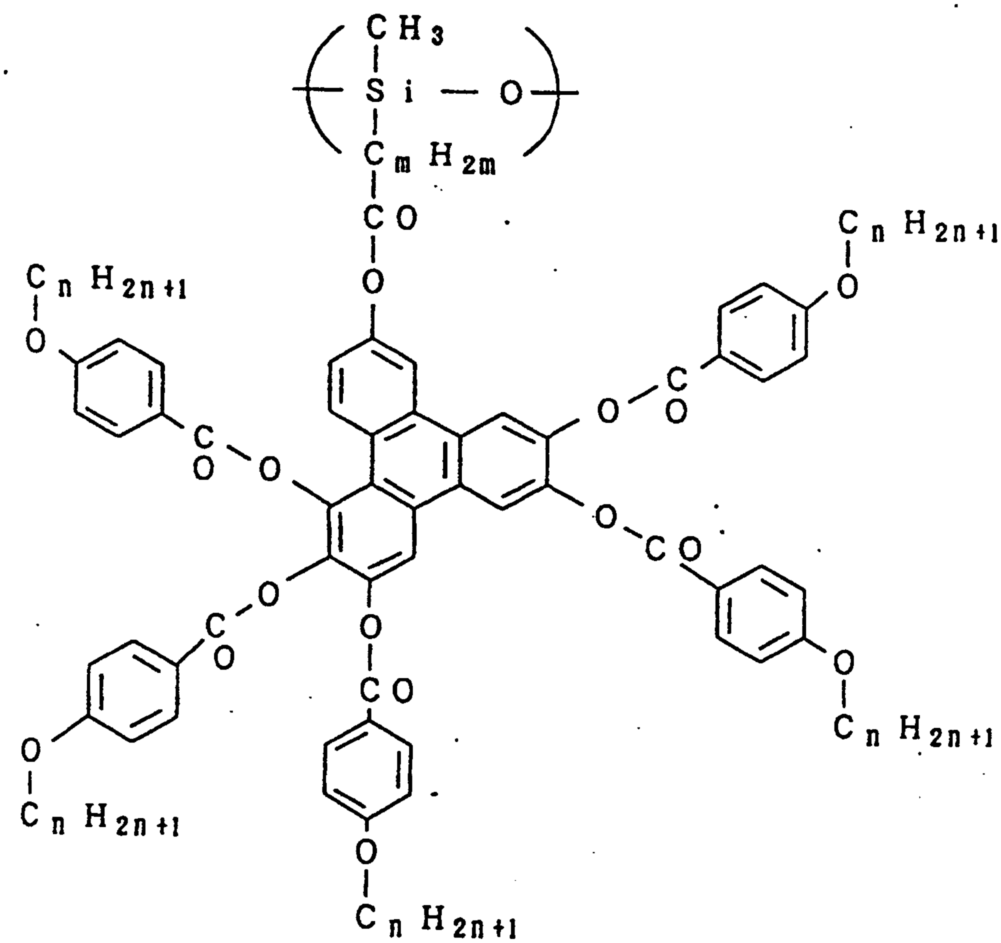


wherein n is an integer of 1-18, preferably 3-14.



wherein n is an integer of 1-18, preferably 3-14. m is an integer of 2-16, preferably 4-12.

The average molecular weight of the above polymers are 5,000 - 100,000.

The above structural formulas are typical examples of the discotic liquid crystalline compounds employable in the invention and there is made no limitation thereto. Discotic liquid crystalline compounds of any structure may each be used alone or in the form of a composition in so far as they possess any of the foregoing properties.

As the discotic liquid crystalline material, in order to avoid transition from liquid crystal phase to crystal phase, there is used a compound wherein all of plural substituent groups attached to mesogen are not the same. When a compound wherein all of the substituent groups are the same, it is desirable to use the compound as a composition with at least one another compound different (in mesogen and/or substituent groups) from the compound.

Most of the discotic liquid crystalline compounds contain many ether linkages or ester linkages in the molecule. Known reaction methods are adoptable for the formation of those linkages. For example, for the formation of ether linkages, there may be adopted the Williamson method involving a nucleophilic substitution reaction of alkoxide ion with a primary alkyl halide. For the formation of ester linkages there may be used, for example, an acid chloride method involving reaction of an acid chloride with an alcohol, or a deacetylation reaction which is the reaction of an acetylated compound of alcohol with an carboxylic acid. There is no special limitation. Each discotic crystalline compound employable in the present invention is not required to undergo a reaction control such as selecting a substituent group at each substitution site of a discogen constituting compound. For this reason, for example, though a concrete description of a structural formula is difficult, it is possible to react in a single reaction system the discogen constituting compound with compounds capable of becoming a variety of substituent groups in a larger number than the number of substitution sites of the discotic liquid crystalline compound to afford a discotic liquid-crystalline compound or a composition containing the said compound. In this case, it is possible that a certain substituent group will not be bound in the molecule of a certain discogen constituting compound but be bound in the molecule of another compound. In the present invention, since the transition from liquid crystal phase to crystal phase is not desirable, the use of such various kinds of substituent groups as mentioned above is preferred, in deteriorating the symmetricity of the molecular structure.

For obtaining a liquid crystalline optical film with a uniformly fixed hybrid orientation, using the above discotic liquid

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crystalline material, it is desirable in the invention to use a substrate which will be described below and go through the following steps.

Reference will be made first to the substrate (hereinafter referred to as "alignment substrate").

In order to obtain the hybrid orientation in the present invention, it is preferred that the layer of the discotic liquid crystalline material is sandwiched in between different upper and lower interfaces. If the layer is sandwiched in between the same upper and lower interfaces, the orientation at the upper interface of the layer and that at the lower interface of the layer will become the same, thins making it difficult to obtain the hybrid orientation.

According to a concrete embodiment, an alignment substrate and an air interface are utilized and the lower surface of the discotic liquid crystalline layer is brought into contact with the alignment substrate, while the upper surface thereof is contacted with the air. It is also possible to use upper and lower substrates of different substrates, but in point of manufacturing process it is preferable to use a single alignment substrate and an air interface.

The alignment substrate employable in the present invention preferably has anisotropy so that a tilting direction of liquid crystal (projection of directors to the alignment substrate) can be defined. If the alignment substrate used cannot define the tilting direction of liquid crystal, there will be obtained only a disorderly tilted structure (disordered vectors of projected directors to the substrate).

As the alignment substrate employable in the present invention, one having anisotropy in a plane is preferred. Examples are film substrates of plastics such as polyimides, polyamide-imides, polyamides, polyether ketones, polyketone sulfides, polyether sulfon, polysulfon, polyphenylene sulfides, polyphenylene oxides, polyethylene terephthalates, polybutylene terephthalates, polyethylene naphthalates, polyacetals, polycarbonates, polyarylates, acrylic resins, polyvinyl alcohols, polypropylenes, cellulosic plastics, epoxy resins, and phenolic resins, uniaxially stretched film substrates thereof, metallic substrates such as aluminum, iron, and copper substrates with slits formed in the surfaces thereof, and glass substrates such as alkali glass, borosilicate glass and flint glass substrates having etched slits in the surfaces thereof.

The substrates exemplified above may have been subjected to a surface treatments such as a hydrophilicizing or hydrophobicizing treatment. Also employable are rubbing-treated plastic film substrates obtained by rubbing the plastic film substrates exemplified above, as well as the above-exemplified substrates having rubbing-treated plastic film such as, for example, rubbing-treated polyimide films and rubbing-treated polyvinyl alcohol films. Further employable are the above exemplified substrates having an obliquely vapor-deposited film of silicon oxide.

Among the above various alignment substrates, as examples of those suitable for forming such a hybrid orientation of discotic liquid crystal as in the present invention there are mentioned substrates having a rubbing-treated polyimide film, as well as rubbing-treated polyimide, polyether ether ketone, polyether ketone, polyether sulfone, polyphenylene sulfide, polyethylene terephthalate, polyethylene naphthalate and polyarylate substrates, further, cellulosic plastic substrates.

In the liquid crystalline optical film of the present invention, the angle of the discotic liquid crystal directors relative to the film plane is different between the upper surface and the lower surface of the film. At the substrate-side film surface the said angle can be adjusted in the range of 60° to 90° or in the range of 0° to 50°. In view of the manufacturing process it is preferable that the angle between the discotic liquid crystal directors in the vicinity of the film interface with the orienting substrate be adjusted in the range of 60° to 90°.

The liquid crystalline optical film of the present invention is obtained by applying the foregoing discotic liquid crystalline material onto the alignment substrate and then going through uniform orienting and fixing steps.

The application of the discotic liquid crystalline material can be effected by using a solution of the discotic liquid crystalline material in any of various solvents or by using the said material in a molten condition. But the former, namely, solution application is preferred.

The following description is now provided about the solution application.

A solution containing a predetermined concentration of the discotic liquid crystalline material is prepared by dissolving the same material in a solvent. As the solvent there usually is employed, though depending also on the kind of the discotic liquid crystalline material used, any of halogenated hydrocarbons such as chloroform, dichloromethane, carbon tetrachloride, dichloroethane, tetrachloroethane, trichloroethylene, tetrachloroethylene, chlorobenzene and o-dichlorobenzene, phenols such as phenol and p-chlorophenol, aromatic hydrocarbons such as benzene, toluene, xylene, methoxybenzene and 1,2-dimethoxybenzens, as well as acetone, ethyl acetate, t-butyl alcohol, glycerol, ethylene glycol, triethylene glycol, ethylene glycol monomethyl ether, diethylene glycol dimethyl ether, ethyl cellosolve, butyl cellosolve, 2-pyrrolidone, N-methyl-2-pyrrolidone, pyridine, triethylamine, dimethylformamide, dimethylacetamide, acetonitrile, butyronitrile, carbon disulfide, and mixture thereof.

The concentration of the solution cannot be said sweepingly because it depends on the solubility of the discotic liquid crystalline material used and the thickness of the desired liquid crystalline optical film, but usually it is in the range of 1 to 60 wt%, preferably 3 to 40 wt%.

The solution of the discotic liquid crystalline material thus prepared is then applied onto the alignment substrate described above, for example by spin coating method, roll coating method, or printing method, dipping/pulling-up

method die coating method.

Thereafter, the solvent is removed, allowing a layer of the discotic liquid crystalline material having a uniform thickness to be formed on the substrate. Conditions for removing the solvent are not specially limited if only the solvent can mostly be removed and the material layer does not flow or drop. Usually the solvent is removed by air-drying at room temperature, drying on a hot plate, drying in a drying oven, or the spray of warm or hot air.

This solution applying and drying step intends to form a layer of the discotic liquid crystalline material having a uniform thickness on the substrate, in which stage the liquid crystalline material layer does not form a hybrid orientation yet. For forming a hybrid orientation it is desirable in the present invention to perform the following heat treatment.

The heat treatment is conducted at a temperature of not lower than the liquid crystal transition point of the discotic liquid crystalline material. More specifically, orientation is allowed to take place in the state of liquid crystal of the material. Alternatively, the material is once brought into an isotropic liquid state at a temperature higher than the temperature range in which liquid crystal phase is presented, and thereafter the temperature is dropped to the temperature range.

The heat treatment temperature is usually in the range of 50°C to 300°C, preferably 100°C to 250°C.

As to the time required for satisfactory orientation of liquid crystal, it cannot be said sweepingly because it differs depending on the kind of the discotic liquid crystalline material used. But said time is usually in the range of 5 seconds to 2 hours, preferably 10 seconds to 40 minutes, more preferably 20 seconds to 20 minutes. If the time is shorter than 5 seconds, it is likely that the temperature of the discotic liquid crystalline material layer will not rise up to a predetermined level, resulting in unsatisfactory orientation. A longer time than 2 hours is not desirable because of deterioration of productivity.

Through the above steps it is possible to form a hybrid orientation in the state of liquid crystal.

In the above heat treatment step there may be used a magnetic or electric field for orienting the discotic liquid crystalline material. However, if a magnetic or electric field is applied while heat treatment is performed, a uniform field force acts on the liquid crystalline material layer, so that the liquid crystal layers are apt to face in a certain direction and hence it becomes difficult to obtain the hybrid orientation intended in the invention in which the directors are changed in the film thickness direction. If the field force is removed after an orientation other than the hybrid orientation, e.g. homeotropic orientation or tilt orientation, is formed, it is possible to obtain a thermally stable hybrid orientation. However, this brings about no special merits in the manufacturing process.

The hybrid orientation in the state of liquid crystal thus obtained is then cooled, whereby the orientation form is fixed without impairment, thus affording the liquid crystalline optical film of the present invention.

Generally, in the case where a crystalline phase appears in the course of cooling, the orientation in the state of liquid crystal is destroyed with crystallization. In contrast therewith, the discotic liquid crystalline material used in the present invention does not have any crystalline phase, or even when it has a crystalline phase latently, the crystal phase does not appear during cooling, or although a clear crystal transition point or liquid crystal transition point is not confirmed, the material does not exhibit fluidity in the working temperature range of the film nor does its orientation form change even under the application of an external field or force. Since the liquid crystalline material used possesses such a property, the orientation form is not destroyed by crystallization.

The liquid crystalline optical film of the present invention can be suitably obtained by cooling it to not higher than the liquid crystal phase transition point of the discotic liquid crystalline material. For cooling, it suffices to take out the discotic liquid crystalline material from the heat treatment atmosphere into the atmosphere of room temperature, whereby the discotic liquid crystal can be fixed uniformly. Moreover, forced cooling such as air cooling or water cooling, or slow cooling, may be performed, and no limitation is placed on the cooling speed.

In the hybrid orientation obtained according to the present invention, the angle in the film thickness direction is set in such a manner that the absolute value of the angle between the film directors and the film plane is in the range of 60° to 90° at one of the vicinities of the upper and lower interfaces of the film, while at the opposite surface in the range of 0° to 50°, the angle can be set to a desired value by suitably selecting the discotic liquid crystalline material or orienting substrate to be used. Moreover, even after formation of the film, adjustment to desired angles can be made by adopting a method of scraping the film surface uniformly or a method of dissolving the film surface uniformly in a solvent. The solvent to be used is suitably selected according to the kind of the discotic liquid crystalline material used and that of the alignment substrate used.

The liquid crystalline optical film of the present invention obtained by the above steps can exhibit various properties according to alignment because the hybrid orientation which cannot be obtained by conventional discotic liquid crystal is uniformly formed and stabilized, and the upper and lower parts of the film are not equal due to such an orientation form, and anisotropy exists in the in-plane direction.

When the liquid crystalline optical film of the present invention is used for an optical element, for example, when this film is arranged in a liquid crystal cell as a compensating film, the above-mentioned alignment substrate is peeled from the optical film so that the liquid crystalline optical film is used alone, the liquid crystalline optical film is used as formed on the alignment substrate, or the liquid crystalline optical film is laminated to another substrate different from the alignment film so as to be used.

When the liquid crystalline optical film is used alone, the alignment substrate is peeled from the liquid crystalline optical film at the interface, for example by a peeling method using rolls, a method involving dipping in a poor solvent which is poor for all of the constituent materials and subsequent mechanical peeling, a peeling method using an ultrasonic wave in a poor solvent, a peeling method which utilizes a temperature change based on the difference in thermal expansion coefficient between the alignment substrate and the film, or a method of dissolving off the alignment substrate or an alignment film formed on the alignment substrate. Since the peelability differs depending on the adherence between the discotic liquid crystalline material used and the alignment substrate used, there should be adopted a method most suitable for the system used.

Next, in the case of using the liquid crystalline optical film as formed on the alignment substrate, if the alignment substrate is transparent and optically isotropic, or if the alignment substrate is opaque or optically anisotropy, the liquid crystalline film formed on the alignment substrate may be used as a compensating element as long as it can be used as an optical element, that is, the compensating element.

For example, in the case of using an opaque substrate such as a metallic thin film, it can be used for an application utilizing reflection property.

The liquid crystalline optical film of the present invention obtained by orientation-fixing the discotic liquid crystalline material on the alignment substrate may be peeled from the substrate, then laminated to another substrate more suitable for an optical use, and the resulting laminate constituted at least by both the liquid crystalline optical film and another substrate different from the alignment substrate may be used as an optical element, that is a compensating element.

For example, in the case where the alignment substrate used is necessary for obtaining the hybrid orientation form but exerts an undesirable influence on an liquid crystal display, the substrate may be removed from the liquid crystalline optical film after fixing the orientation form. More specifically, there may be adopted the following method.

A substrate (hereinafter, referred to as the "second substrate") suitable for a liquid crystal display element to be incorporated in a liquid crystal display and the liquid crystalline optical film on the alignment substrate are affixed together using an adhesive or a pressure-sensitive adhesive. Next, the alignment substrate and the liquid crystalline optical film are peeled from each other at the interface, and the liquid crystalline optical film is transferred onto the side of the second substrate suitable for a liquid crystal display, whereby the compensating element can be produced.

The second substrate to be used for the transfer is not particularly limited if only it has a moderate flatness. For example, in the case of a transparent optical element, a glass substrate or a transparent plastic film having optical isotropy is preferred. As examples of such a plastic film there are mentioned films of polymethacrylates, polystyrenes, polycarbonates, polyether sulfones, polyphenylene sulfides, polyarylates, amorphous polyolefins, triacetyl cellulose, and epoxy resins. Particularly preferred are films of polymethyl methacrylates, polycarbonates, polyarylates, triacetyl cellulose, and polyether sulfones. Even in the case of an optically anisotropic film, it may be used as it is if it can be used suitably for a desired optical element. Examples of such an optically anisotropic film includes retardation films such as a stretched polyethylene terephthalate film or polycarbonate.

A further examples of the transparent second substrate is a polarizing sheet. The polarizing sheet is an optical element necessary for a liquid crystal display. It is very preferable that the polarizing sheet is used as a substrate, because a new optical element can be obtained by laminating the liquid crystalline optical film of the present invention to the polarizing sheet.

A further example of the second substrate used may be made of a liquid crystal driving cell itself. The liquid crystal cell employs two upper and lower glass substrates each provided with an electrode. By transferring the liquid crystalline optical film of the present invention onto one or both of the upper and lower glass substrates, the glass itself of the cell becomes the desired supporting substrate for the optical film. Of course, by using the glass substrates forming the display cell as the alignment substrates, the liquid crystalline optical film of the present invention can be prepared.

Meanwhile, in the case where the liquid crystalline optical film of the present invention is used for a reflecting optical element, examples of the substrate used for the transfer are a transparent and opaque glass plate, a plastic film or a metallic plate. Such a metallic plate includes copper, stainless and aluminum.

It is not necessary that the second substrate described above essentially has an anchoring effect for the discotic liquid crystal. Moreover, it is not necessary to provide an alignment film between the second substrate and the liquid crystalline optical film.

The adhesive or pressure-sensitive adhesive for affixing the second substrate for transfer and the liquid crystalline optical film of the present invention is not specially limited insofar as it is of an optical grade. For example, there may be used an adhesive or pressure-sensitive adhesive prepared from acrylic resin, epoxy resin, ethylene-vinyl acetate copolymer, rubber, urethane resin, or a mixture thereof. The adhesive may be a thermosetting type, photocuring type or electron beam curing type, provided it is necessary for the adhesive to possess optical isotropy.

The transfer onto the second substrate which is suitable for the optical element made of the liquid crystalline optical film of the present invention is performed by peeling the alignment substrate from the optical film at the interface after adhesion. As mentioned above, examples of a peeling method are a peeling method using rolls, a method involving dip-

ping in a poor solvent which is poor for all of the constituent materials and subsequent mechanical peeling, a peeling method using an ultrasonic wave in a poor solvent, a peeling method which utilizes a temperature change based on the difference in thermal expansion coefficient between the alignment substrate and the film, or a method of dissolving off the alignment substrate or an alignment film formed on the alignment substrate. Since the peelability differs depending on the adherence between the discotic liquid crystalline material used and the alignment substrate used, there should be adopted a method most suitable for the system used.

By the transfer onto the second substrate described above it is possible to obtain an optical element, that is, a compensating element wherein the angle between the discotic liquid crystal directors located near the film interface on the substrate side and the film plane is usually in the range of 0° to 50°.

On the surface of the liquid crystalline optical film of the present invention there may be disposed a protective film such as a transparent plastic film for surface protection.

The liquid crystalline optical film of the present invention is obtained by fixing the orientation form so as to form the hybrid orientation which cannot be obtained by conventional discotic liquid crystal. The liquid crystalline optical film exhibits a peculiar optical effect for a light, and thus it may be used for various optical applications including an optical element. Therefore, the liquid crystalline optical film has great industrial value.

The following describes the case where the liquid crystalline optical film of the present invention is used as a compensating film for a liquid crystal display element (hereinafter referred to as "compensating film").

The compensating film of the present invention obtained as mentioned above shows a viewing angle compensation effect (viewing angle improvement effect) for a liquid crystal display having optical anisotropy. The type of the liquid crystal display is not specially limited, but concrete examples of the display are displays utilizing twisted nematic liquid crystal orientation such as a TN (twisted nematic) liquid crystal display and an STN (super twisted nematic) liquid crystal display, a super homeotropic liquid crystal display (J.F. Clerc, M. Aizawa, S. Yamauchi, J. Duchene: JAPAN DISPLAY '89 P. 188 (1898)), an OCB (optically compensated birefringence) mode liquid crystal display, an ECB (electrically controlled birefringence) mode liquid crystal display, a macromolecular dispersion liquid crystal display, a guest-host mode liquid crystal display and an anti-ferroelectric liquid crystal display. A display system includes a direct-view-type display system, a projection-type display system and a reflection-type display system.

As one of liquid crystal displays in which the compensating film of the present invention shows the viewing angle compensation effect most remarkably, there is a TN liquid crystal display which is driven by a normally-white mode. The TN liquid crystal display is classified according the driving method into a simple matrix method and an active-matrix method using a TFT (thin film transistor) electrode or a MIM (metal insulator metal) electrode. In the present invention, a difference in the driving method is not essence, and the orientation form of liquid crystal in a liquid crystal driving cell (hereinafter referred to "liquid crystal cell") determines the viewing angle property of a liquid crystal display. The liquid crystal cell here is a TN liquid crystal cell, and the twist angle of the liquid crystal cell is in the range of 70° to 110°. The most general TN liquid crystal display employs a liquid crystal cell having the twist angle of about 90°. A retardation value at the time of not applying a voltage to the liquid crystal cell is usually in the range of 200 nm to 1200 nm, and preferably 400 nm to 600 nm. The retardation value of approximately 490 nm is used most widely. Transmission axes of the upper and lower polarizing sheets sandwiching the liquid crystal cell substantially intersect perpendicularly to each other at the time of driving the liquid crystal display by the normally white mode driving. Namely, the angle of the transmission axes of the two polarizing sheets is usually 90° ± 20°, preferably 90° ± 10°, particularly preferably 90°.

In addition, the TN liquid crystal display employs two modes according to the orientation restricting direction of the liquid crystal cell substrate and the arrangement of the polarizing sheet. One is a birefringence mode in which the orientation restricting direction at the substrate interface of the TN liquid crystal cell and the transmission axial direction of the polarizing plate are not parallel with and does not intersect perpendicularly to each other. The other is a rotatory mode in which the orientation restricting direction and the transmission axial direction of the polarizing plate are parallel with or intersect perpendicularly to each other. In the birefringence mode, the angle between the orientation restricting direction and the transmission axis of the polarizing plate is usually in the range of 20° to 70°, preferably 35° to 55°, more preferably 40° to 50° when the absolute value of the angle is represented by an acute angle of 0° to 90°. In the rotatory mode, the angle is essentially a multiple of 90°.

The compensating film of the present invention shows the viewing angle compensating effect for a liquid crystal display employing both the birefringence mode and the rotatory mode using the TN liquid crystal cell.

The orientation direction of the TN liquid crystal cell can be restricted usually by after forming an organic thin film made of polyimide or polyvinyl alcohol on the surface of the cell substrate, carrying out a rubbing process.

The pixel dividing method in which a driving electrode is divided, a dual domain method in which a pre-tilt direction of liquid crystal is divided into two direction or into multi-directions and a multi-domain method which are public knowledge are designed in order to enlarge the viewing angle of a liquid crystal display system on the liquid crystal cell side. By these methods, the compensating film of the present invention works efficiently on a liquid crystal display in which the viewing angle is improved to some degree, and thus it is possible to further enlarge the viewing angle.

The thickness of compensating film, which shows the viewing angle compensating effect for various liquid crystal

displays having anisotropy, depends on a method, a type and an optical parameter of an objective liquid crystal display. For this reason, the thickness cannot be determined sweepingly, but is usually in the rage of 0.1 μm to 100 μm, preferably 0.1 μm to 40 μm, more preferably 0.2 μm to 20 μm, particularly preferably 0.4 μm to 10 μm. If the film thickness is less than 0.1 μm, the satisfactory compensating effect might not be obtained. If the film thickness exceeds 100 μm, the display on a screen might be colored excessively. Thus, this case is not desirable.

In order to efficiently draw out the ability of the compensating film according to the present invention, it is preferable that the parameter and the axial arrangement of the compensating film should be considered in detail. The following exemplifies optimization of the parameter and axial arrangement of the compensating film according to the present invention in the case where the TN liquid crystal display employing the normally white mode is used.

In general, optical parameters and physical property values which characterize the constitution of the compensating film are an angle of directors, a film thickness, an apparent in-plane retardation and an average tilt angle. The description thereof will be given as follows.

First, it is preferable that an angle between the directors of the discotic liquid crystal and the plane of the compensating film is in the range of 60° to 90° in one of the vicinities of the upper interface and lower interface of the compensating film, and in the range of 0° to 50° on the other side. If this condition is not satisfied, compensation might not be sufficiently carried out when the refractive index is changed such that the directors of liquid crystal are substantially parallel with the substrate near the substrate interface and substantially perpendicular to the substrate in the center portion of the film thickness direction, which is a characteristic of the refractive index structure at the time of selective display. The angle between the directors of liquid crystal and the plane of the compensating film is more preferably in the range of 70° to 90° in one of the vicinities of the upper interface and lower interface, and in the range of 0° to 30° on the other side.

It is necessary to control the thickness of the compensating film according to relation with a peculiar birefringence value of liquid crystal. The peculiar birefringence value (hereinafter referred to as "Δn) is a difference between a refractive index in the vertical direction to the directors (hereinafter referred to as "no") in the very small area of the discotic liquid crystalline material used for the compensating film and a refractive index in the parallel direction with the directors (hereinafter referred to as "ne"). The refractive indexes can be obtained by utilizing a property such that even if the refractive indexes continuously change, an Abbe refractometer provides information near a measuring interface. Moreover, the refractive indexes can be obtained by measuring a sample which is obtained in such a manner that the discotic liquid crystalline material is sandwiched between two substrates with the same interface and thins the hybrid orientation form is suppressed, and the directors face in one direction. An absolute value of the product of the obtained peculiar birefringence value and the absolute film thickness of the compensating film is in the range of 20 nm to 1000 nm, preferably 50 nm to 600 nm, particularly preferably 100 nm to 400 nm. When the absolute value is in this range, the compensating film of the present invention exhibits a sufficient compensating effect. When the absolute value is less than 20 nm, it is likely that the viewing angle property of a liquid crystal display can be hardly changed. Moreover, when the absolute value exceeds 1000 nm, excessive coloring might occur on liquid crystal display. A plurality of the compensating film of the present invention can be used, but in this case, it is preferable that the absolute value of the product of the peculiar birefringence value and the absolute film thickness is in the aforementioned ranges in each compensating film.

Next, the description will be given as to an apparent in-plane retardation value in the front. Since the directors of liquid crystal are not vertical to the film surface generally in the hybrid orientation described in the present invention, when the film is observed from a direction perpendicular to the film surface, birefringence occurs apparently. The direction obtained when the discotic liquid crystal directors are projected in the film plane corresponds to an apparent fast axis, while the in-plane direction perpendicular to the axis corresponds to a slow axis. The apparent retardation value at the front can be easily obtained by polarization optical measurement such as ellipsometry. The apparent retardation value of the compensating film according to the present invention is usually in the range of 5 nm to 500 nm, more preferably 10 nm to 300 nm, particularly preferably 15 nm to 150 nm against a monochromatic light of 550 nm. If the apparent retardation value is less than 5 nm, the compensating effect might be the same as that of the negative uniaxial structure. Moreover, if the apparent retardation value is larger than 500 nm, excessive coloring of a liquid crystal display might occur when viewed sideways. When a plurality of the compensating films according to the present invention are used, it is preferable that the absolute values of the apparent retardation values of the respective films are in the aforementioned ranges.

The following describes an apparent average tilt angle as the optical parameter. The apparent average tilt angle corresponds an average value of the angle between the directors of liquid crystal and a substrate normal line. This average value can be obtained by adapting the crystal rotation method. The measuring method is as follows.

1) First, sandwich the compensating film of the present invention between polarizers intersecting perpendicularly to each other. At this time, this arrangement is such that a projecting vector of the directors of the discotic liquid crystal on the film surface and a transmission axis of the polarizers make an angle of 45°.

2) Next, tilt the compensating film along the projecting vector of the directors on the film surface, and measure a transmittance.

3) Calculate an average tilt angle according to a relationship between the tilt angle of the compensating film and the transmittance.

Here, a method of placing only one polarizer on the side which is nearer a light source than the compensating film, and polarization-analyzing an emitted light so as to obtain an apparent retardation value can be adopted similarly.

However, since the compensating film has the hybrid orientation, this structure is not completely equivalent to that of the negative uniaxial structure in which light axes face in a constant direction. Namely, the negative uniaxial structure generally has the tilt angle that the transmittance becomes substantially zero, and this is because an incident light goes along the optic axis of a sample (however, a light refraction at the film interface is considered). On the contrary, since the hybrid orientation described in the present invention does not have an optic axis, there exist a tilt angle such that the transmittance becomes zero completely. For this reason, the tilt angle of an uniaxial tilt orientation, in which the minimum value or a curved line showing a relationship between the transmittance and the incident angle is nearest to that of the compensating film is determined as the average tilt angle of the compensating film. The average tilt angle obtained in such a manner is usually in the range of 20° to 60°, preferably 5° to 50°, more preferably 10° to 45°. If the average tilt angle is less than 2°, the compensating effect might be similar to that of the negative uniaxial structure. Moreover, If the average tilt angle exceeds 60°, the average refractive index in the thickness direction becomes too larger than that in the in-plane direction, and thus the satisfactory compensating effect might not be obtained. Here, the average tilt angle corresponds to an average value of the angle in the film thickness direction between the directors of the discotic liquid crystal and the normal line on the film plane.

The above described the angle of the directors, film thickness, apparent in-plane retardation value and average tilt angle as the optical parameters and the physical properties which detail the structure of the compensating film. All the aforementioned values can be measured, and needless to say, it is preferable that they are in the above ranges. However, it becomes difficult to measure these value depending on a construction of the compensating film. In this case, since the values are correlative to each other, at least two of these values are measured, and it is satisfactory that the two values are in the above ranges. In the case the same liquid crystalline material is used for example, and the orientation is obtained in the same manner, in the present invention, the angle of the directors of the discotic liquid crystal near the film interface and the average tilt angle is generally constant irrespective of the film thickness, and the retardation value is proportion to the film thickness.

The following describes the arranging method of the compensating film. The compensating film may be arranged between two polarizing plates of the liquid crystal display, and one or plural compensating films can be arranged. In the present invention, it is practically preferable that the viewing angle is compensated by using one or two compensating films. If more than 3 compensating films are used, the viewing angle can be compensated, but since the cost becomes higher, this case is not desirable. Concrete examples of the arranging position are as follows. However, these examples are typical arranging positions, and thus the present invention is not limited to them.

The following first describes the case of using one compensating film. The compensating film is arranged between the polarizing plate and the liquid crystal cell, and the arranging position may be the upper surface or lower surface of the cell. Here, the vector direction in which the directors of the discotic liquid crystal in the compensating film are projected onto the compensating film plane is referred to as the director direction hereinafter. It is desirable that the director direction is substantially parallel with a transmission axis or an absorbing axis of the adjacent polarizer. Namely, since the compensating film has the hybrid orientation, there exists an apparent retardation when viewed from the front. Therefore, if the director direction of the compensating film is greatly shifted from the transmission axis or absorbing axis of the polarizer, a display quality at the front might be deteriorated due to the retardations. On the contrary, when the directors of the discotic liquid crystal in the compensating film are substantially parallel with the transmission axis or absorbing axis of the polarizer, influence of birefringence of the compensating film is not exhibited at the front. As a result, viewing angle dependence can be compensated without deteriorating the high display quality at the front. Therefore, when the compensating film of the present invention is arranged, the angle between the director direction and the transmission axis or absorbing axis of the polarizing plate is usually ±30°, more preferably ±15°, particularly preferably the director direction coincides with the transmission axis or absorbing axis of the polarizer.

The following describes the case of using two compensating films. The two compensating films are arranged on the upper or lower surface of the liquid crystal cell sandwiched between a pair of polarizing plates. At this time, the two compensating films may be on the one side or the upper and lower sides. The two compensating films may have the same parameter or different parameters. Similarly to the case of using one compensating film, the two compensating film are usually arranged so as to be substantially parallel with the transmission axis or absorbing axis of the polarizer (when a plurality of films are arranged on the upper side of the cell, the upper polarizer) respectively.

However, when the retardations of the two compensating films at the front are substantially equal to each other (a difference is not more than 60 nm, more preferably not more than 30 nm), the two compensating films can be arranged

by making the director directions of the films substantially intersect perpendicularly to each other without being limited by the axis of the polarizing plates. This is because the two compensating films can cancel the apparent retardations at the front each other. Namely, as long as the directors of both the films substantially intersect perpendicularly to each other, the viewing angle can be compensated without deteriorating the display quality at of the liquid crystal display at the front irrespective of the relationship with the axis of the polarizing plate. Needless to say, the case where the respective compensating films are parallel with the transmission axis or absorbing axis of the polarizing plates is preferable. Moreover, it is quite all right that the two compensating films are arranged on the same side or the upper and lower sides of the cell.

Since the compensating films of the present invention have the hybrid orientation, the front and rear surfaces of the compensating film are not equal to each other, and thins the compensating effect slightly differs with which surface is nearer the liquid crystal cell than the other surface. Therefore, a sweeping determination cannot be made as to which surface should placed on the liquid crystal cell. The determination as to which of a surface where the angle between the directors of the discotic liquid crystal and the film plane is larger (in the range of 60° to 90°) or surface where the angle is smaller (in the range of 0° to 50°) is placed on the liquid crystal cell side is made according to the type of a liquid crystal cell various modes of a liquid crystal display. For this reason, it is desirable that the compensating film of the present invention is arranged so as to satisfy the conditions of the liquid crystal cell and various modes.

The use of one or plural the compensating films greatly effects the improvement in the viewing angle of various liquid crystal displays, particularly the TN liquid crystal display. Moreover, the compensating film, together with a conventional optical film such as a film having the negative uniaxial refractive index structure and a film having a positive uniaxial refractive index structure can be used. However, only the compensating film of the present invention plays a conclusive part in the compensation of the viewing angle, so even if any combination of conventional optical films other than the compensating film cannot show a remarkable viewing angle enlarging effect unlike the compensating film of the present invention.

As mentioned above, in the liquid crystal display where at least one compensating film of the present invention is arranged, a slight change in colors and in contrast due to the viewing angle is hardly felt. Moreover, when an area of the display is enlarged, it is possible to display an image uniformly in the center portion and edge portion of the screen.

In addition, as mentioned above, two types of modes, that is, the rotatory mode and the birefringence mode are used according to arrangements of the polarizer and the TN liquid crystal cell substrate. The Compensating film of the present invention can show the satisfactory viewing angle improving effect in both the modes.

EXAMPLES

The following describes examples, but the present invention is not limited to them. In the examples, there were used the following analyzing methods.

(Determination of Chemical Structure)

Determined using ^{1}H-NMR (JNM-GX400, a product of Japan Electron Optics Laboratory Co. Ltd.).

(Observation with Optical Microscope)

Orthoscope observation and conoscope observation were conducted using a polarizing microscope BX-50 (a product of Olympus Optical Co., Ltd.). Identification of a liquid crystal phase was performed by texture observation under heating on a Mettler hot stage (EP-80).

(Polarization Analysis)

Conducted using an ellipsometer DVA-36VWLD (a product of Mizoshiri Kogaku Kogyosho K.K.).

(Measurement of Refractive Index)

Conducted using an Abbe's refractometer Type-4T (a product of Atago K.K.).

(Measurement of Film Thickness)

Conducted using mainly a high-precision thin film step measuring instrument ET-10 (a product of Kosaka Kenkyusho K.K.). There also was adopted a method of determining the film thickness on the basis of both interference wave measurement (an ultraviolet-visible-near infrared spectrophotometer V-570 manufactured by Nippon Bunko Co.) and

Fig. 5

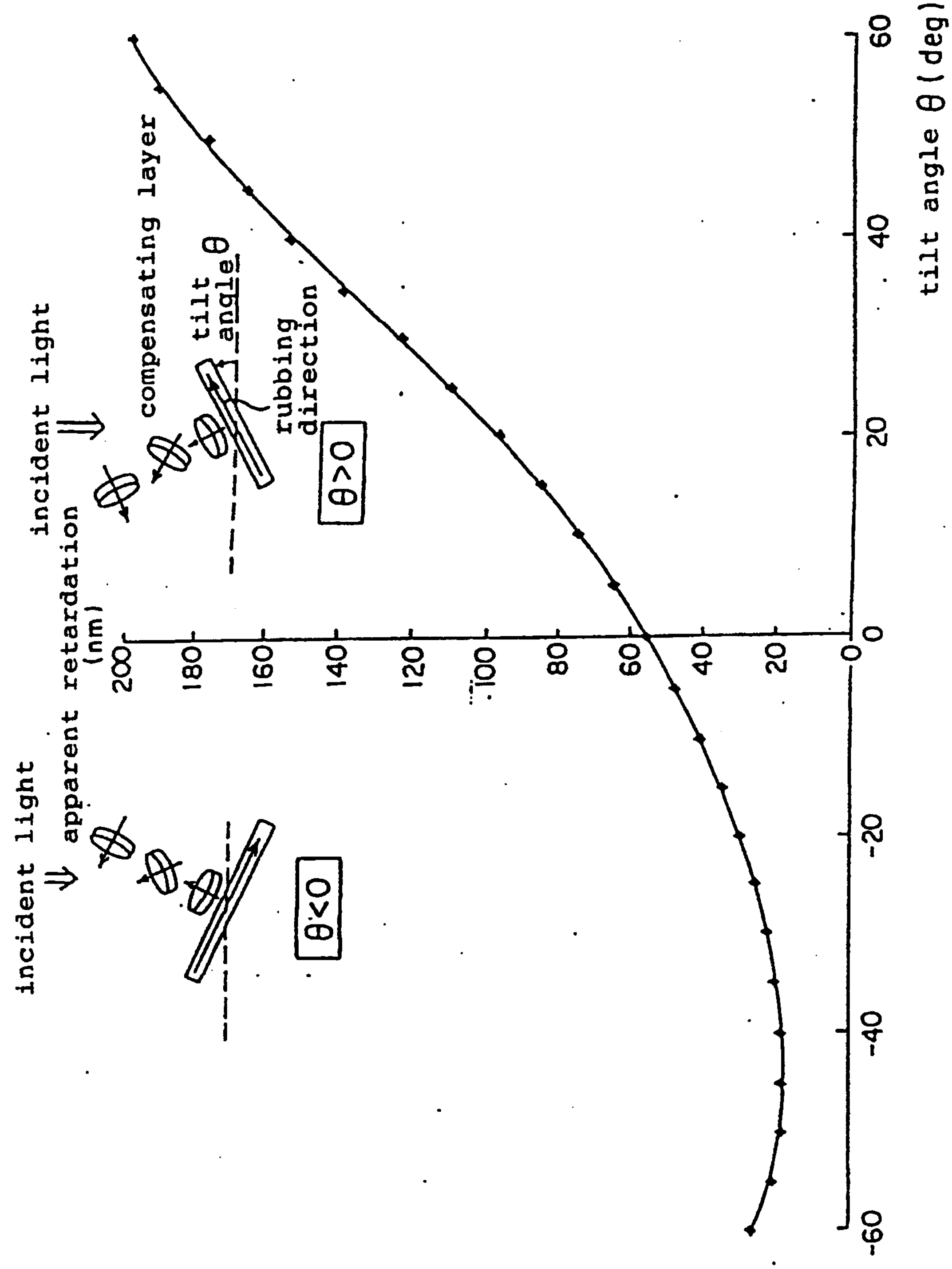

incident light
apparent retardation (nm)
incident light
compensating layer
tilt angle θ
rubbing direction
θ>0
θ<0
200
180
160
140
120
100
80
60
40
20
0
-60
-40
-20
0
20
40
60
tilt angle θ (deg)

Fig. 6

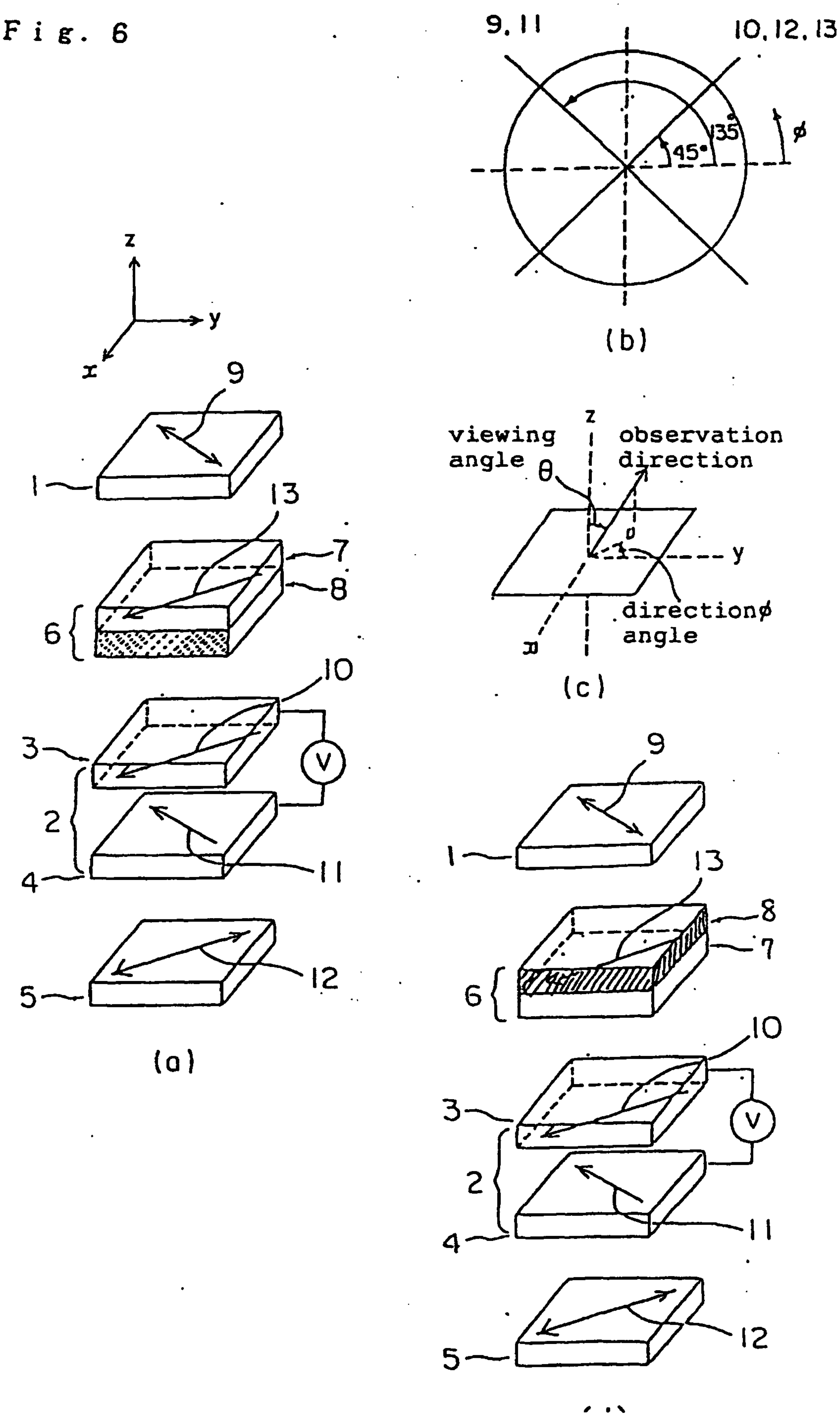
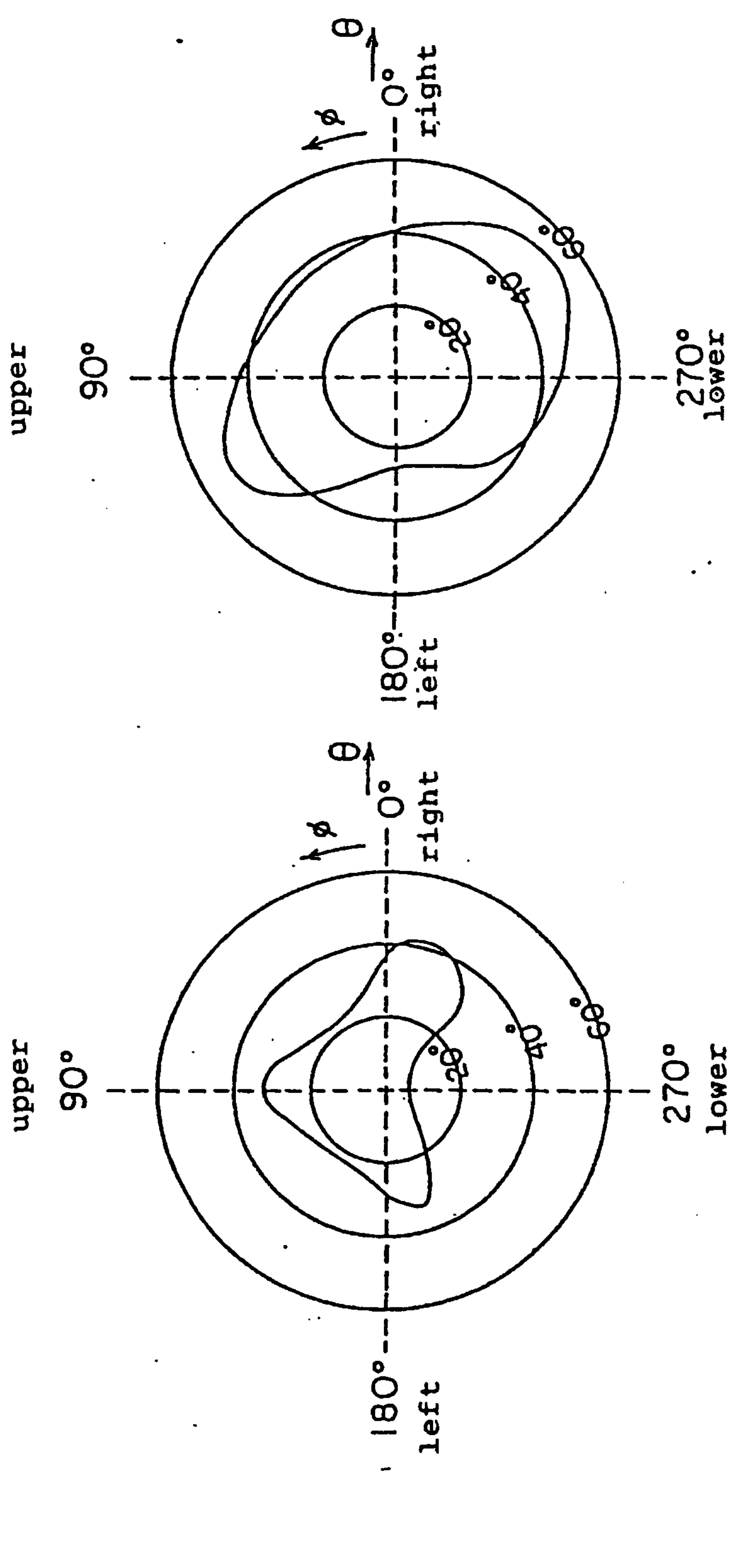

9, 11
10, 12, 13
45°
135°
ϕ
(b)
z
y
x
9
1
13
7
8
6
10
3
V
2
4
11
5
12
(a)
viewing angle θ
observation direction
direction ϕ angle
(c)

Fig. 7



(a) without compensating film

(b) with compensating film

Fig. 8

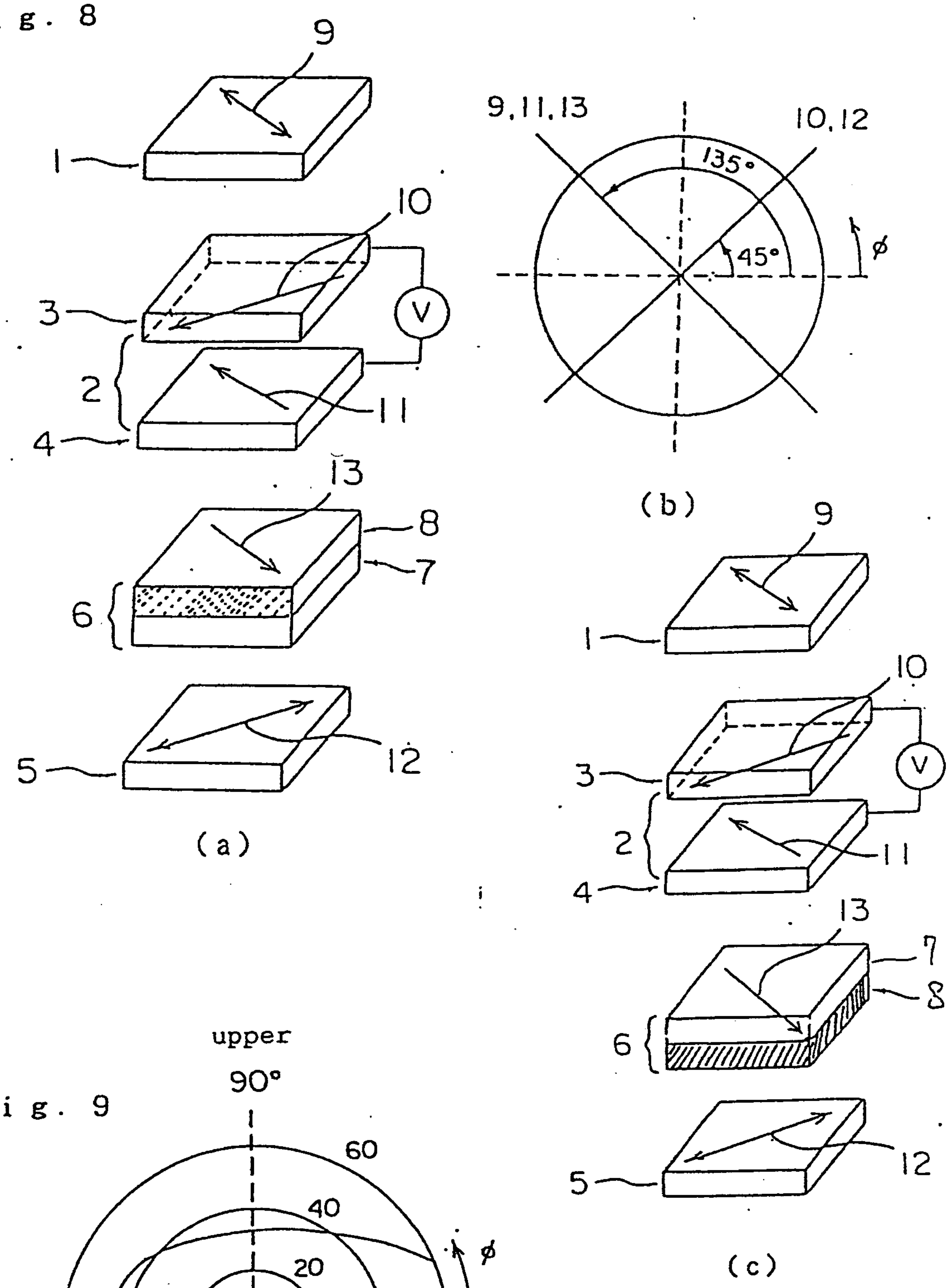

9
1
10
3
V
2
11
4
13
8
7
6
5
12
(a)
9,11,13
10,12
135°
45°
φ
(b)
9
1
10
3
V
2
11
4
13
7
8
6
5
12
(c)

Fig. 9

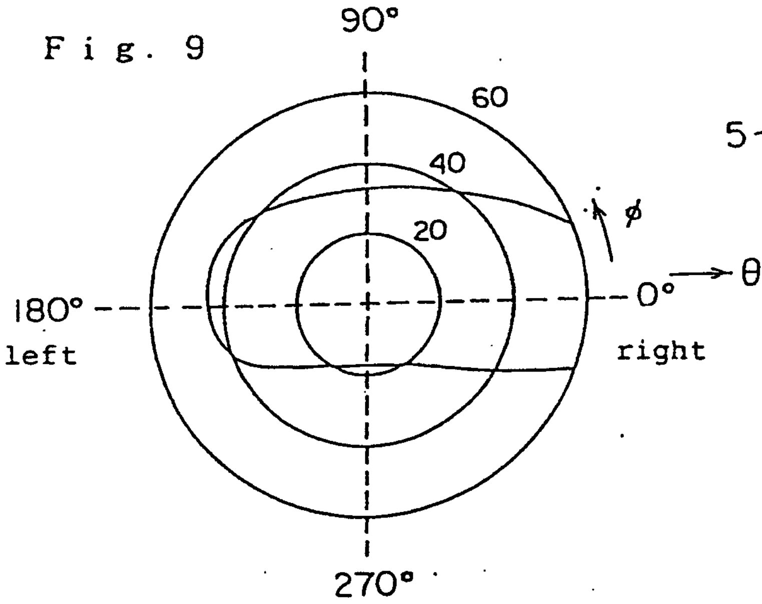
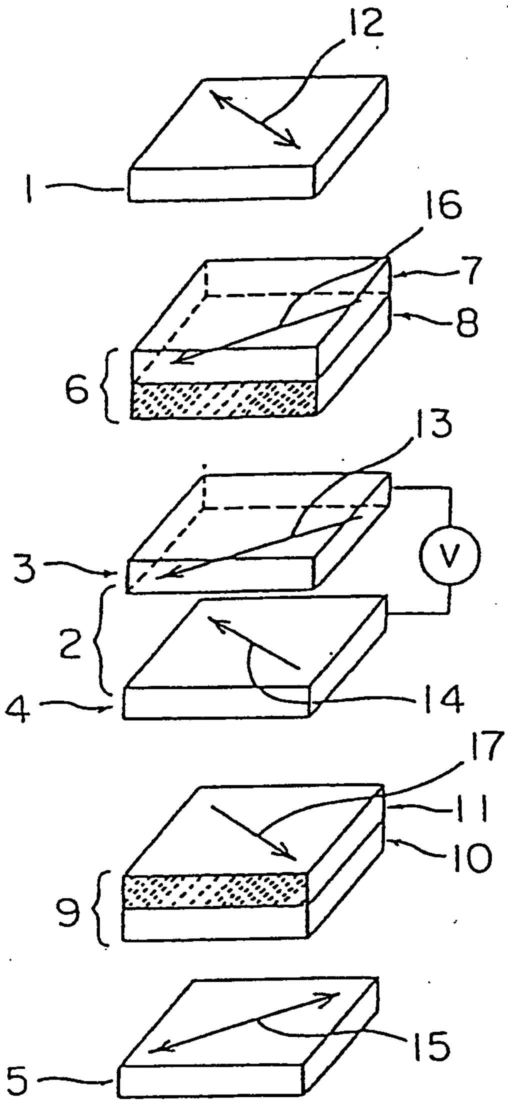
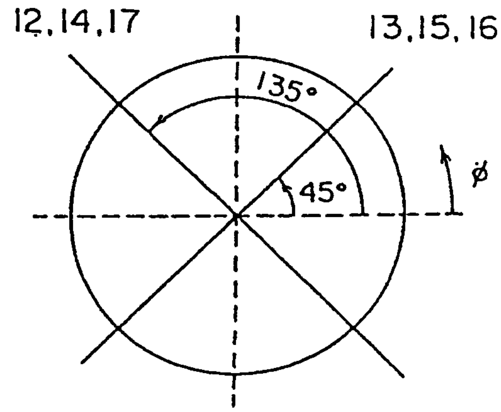

upper
90°
60
40
20
φ
0°
θ
180°
left
right
270°

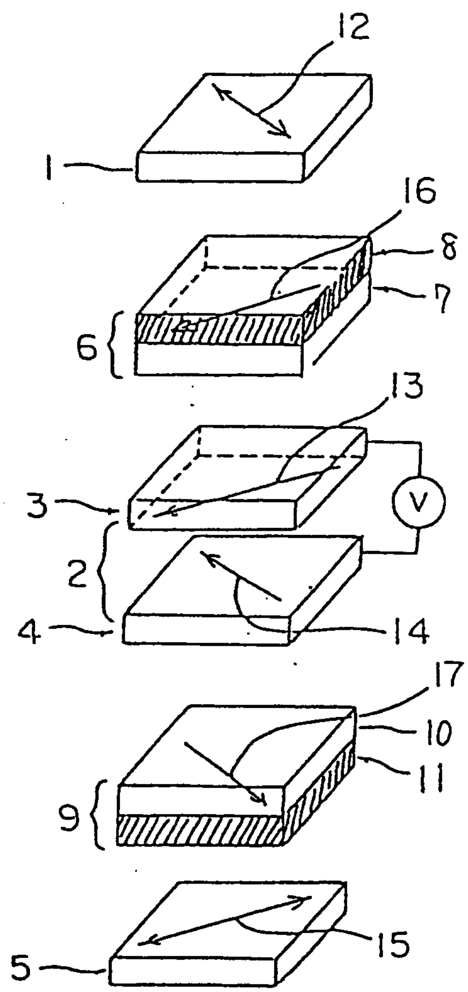
Fig. 10


12
1
16
7
8
6
13
3
V
2
4
14
17
11
10
9
15
5

(a)


12,14,17
13,15,16
135°
45°
ø

(b)


12
1
16
8
7
6
13
3
V
2
4
14
17
10
11
9
15
5

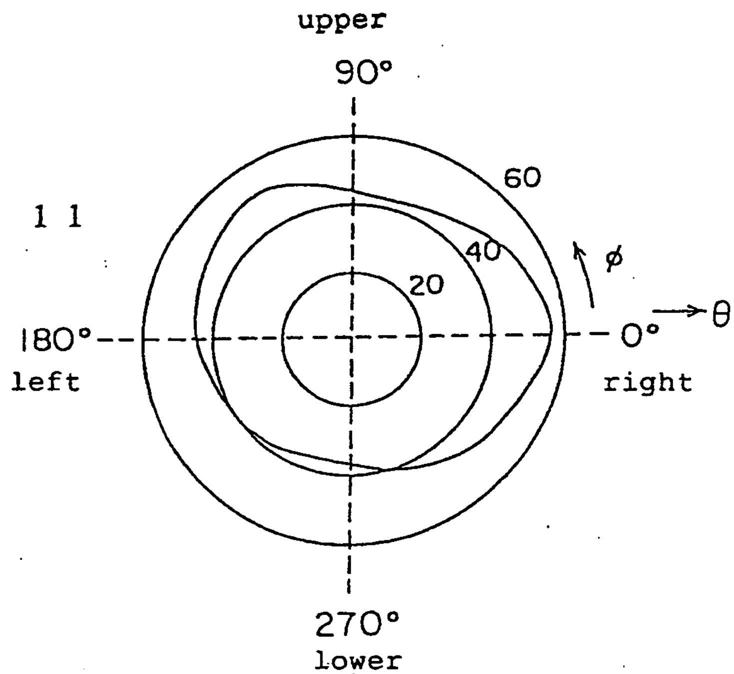

upper
90°
60
40
20
φ
θ
180°
left
0°
right
270°
lower

Fig. 11

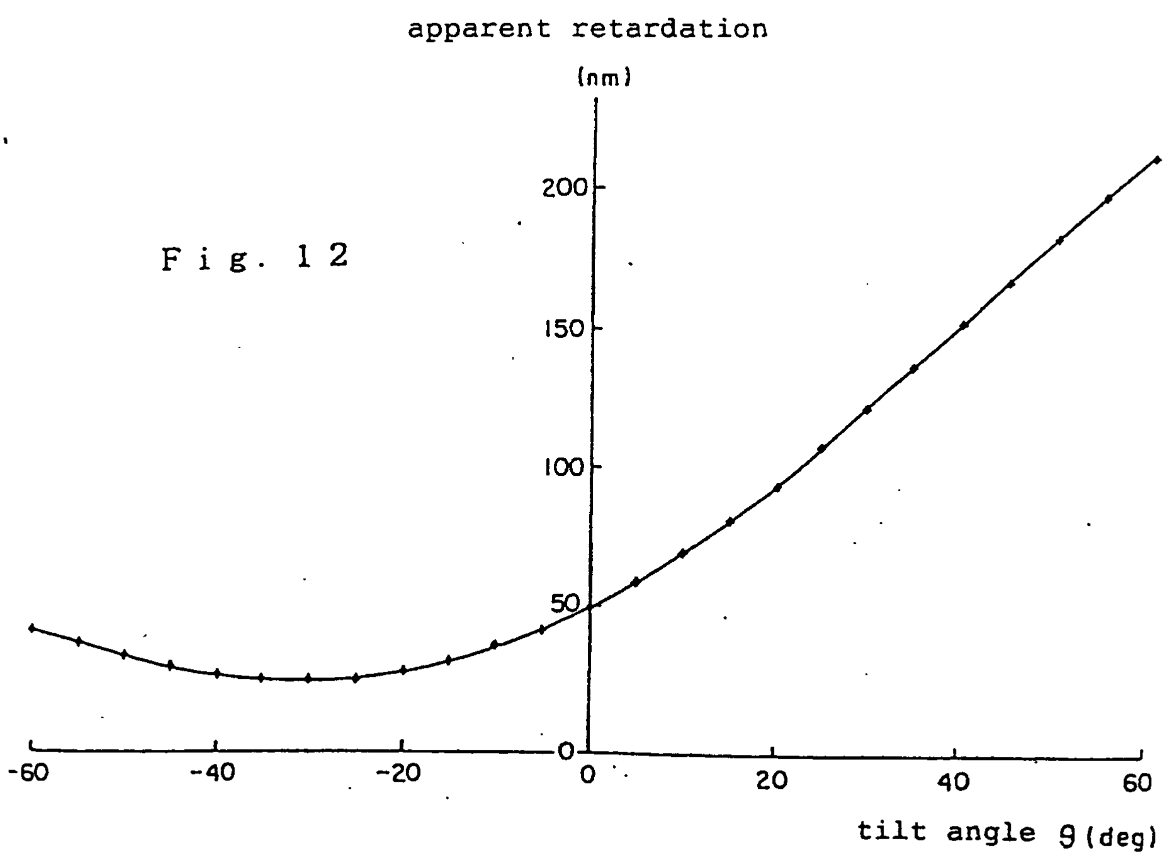
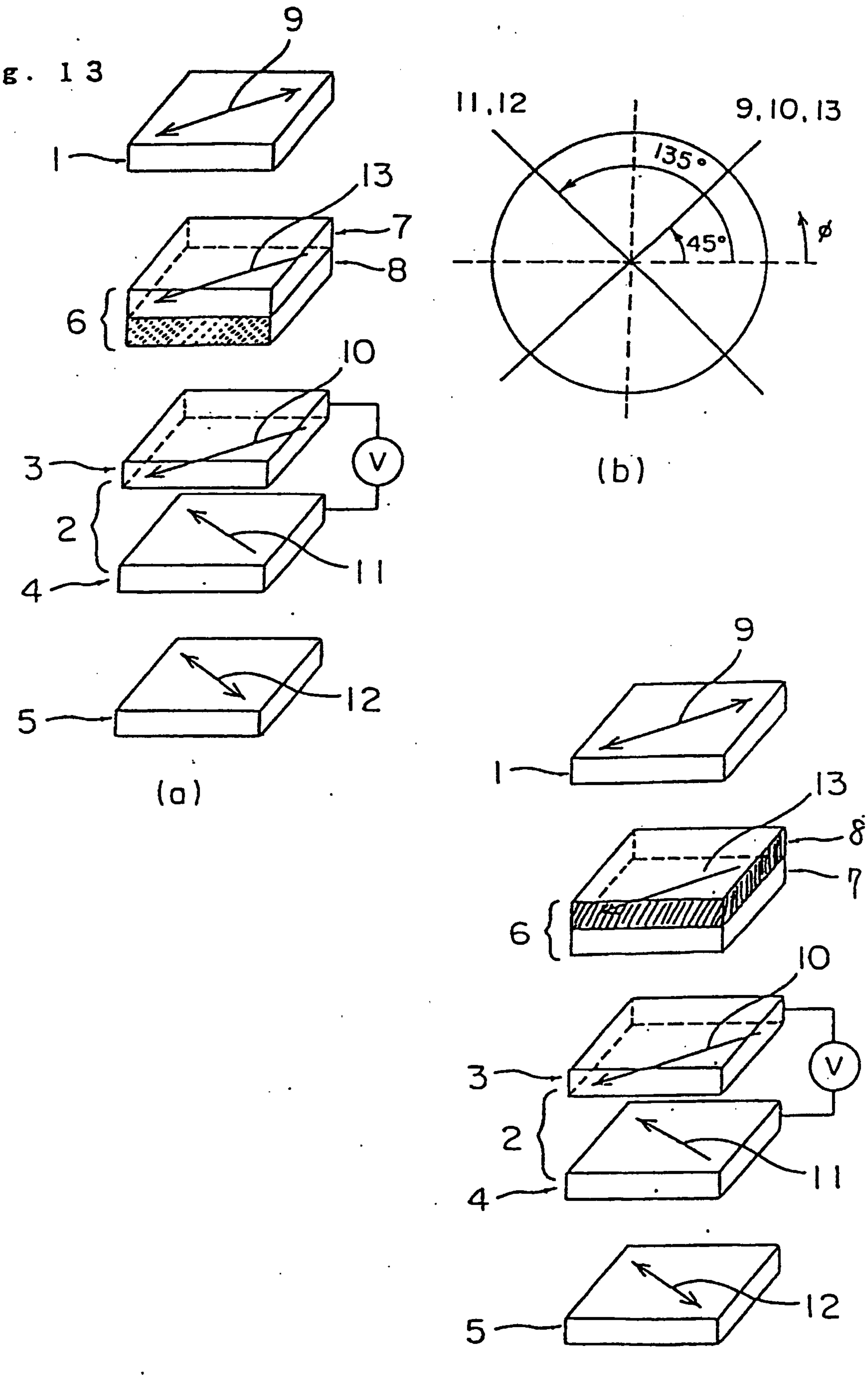

apparent retardation
(nm)
200
150
100
50
0
-60
-40
-20
0
20
40
60
tilt angle θ (deg)

Fig. 12

Fig. 13

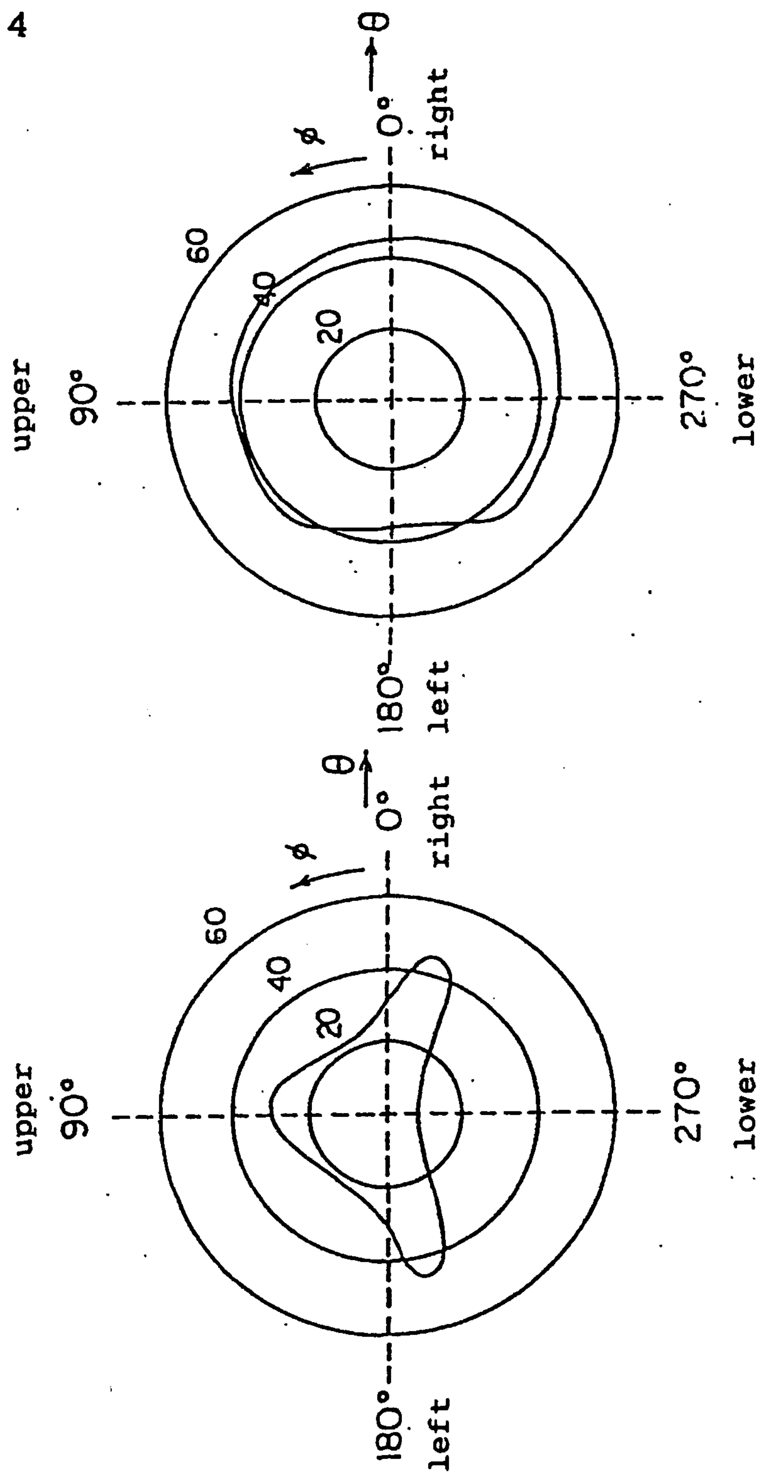

9
1
13
7
8
6
10
3
V
2
4
11
5
12
11,12
9,10,13
135°
45°
ø
9
1
13
8
7
6
10
3
V
2
4
11
5
12

(a)

(b)

(c)

Fig. 14



(a) without compensating film

(B) with compensating film

Fig. 15

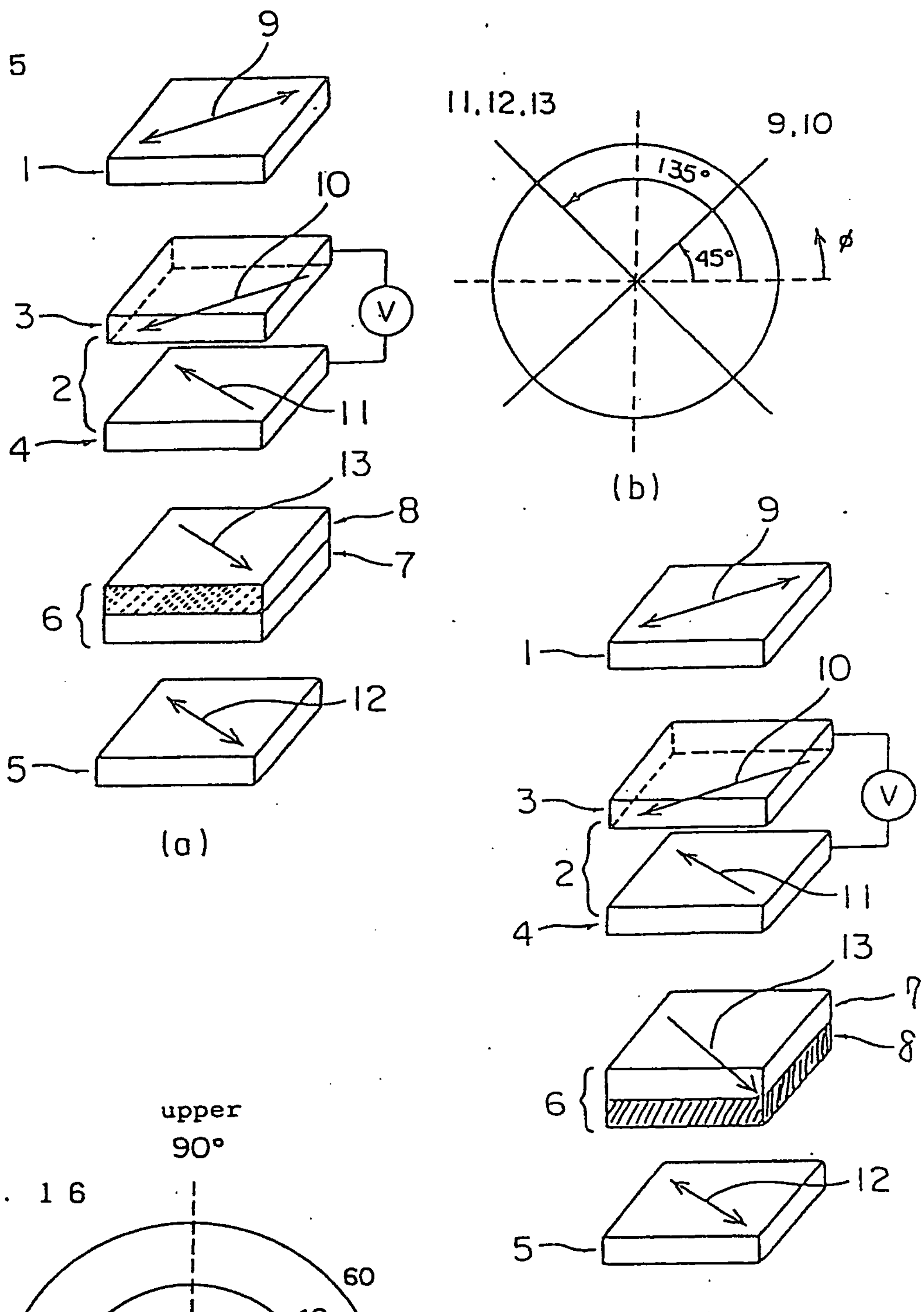

9
1
10
3
V
2
11
4
13
8
7
6
12
5
(a)
11,12,13
9,10
135°
45°
ϕ
(b)
9
1
10
3
V
2
11
4
13
7
8
6
12
5
(c)

Fig. 16

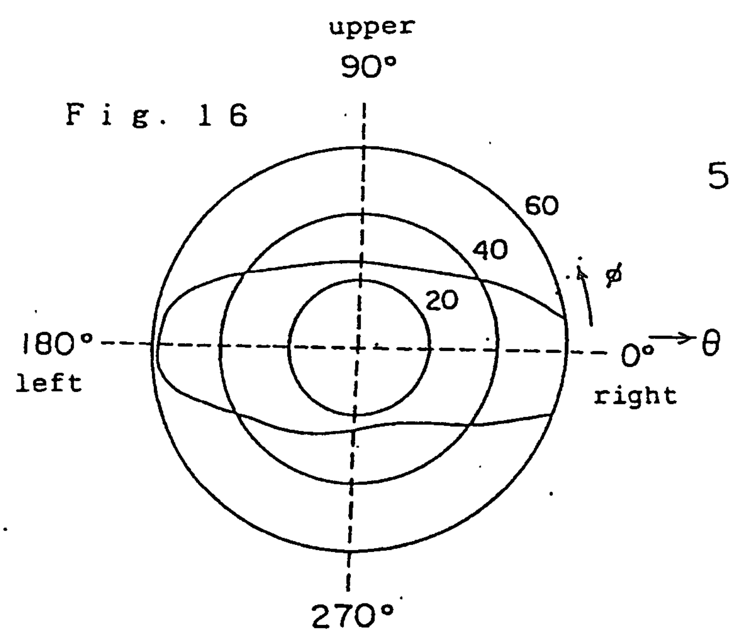

upper
90°
60
40
20
ϕ
180°
left
0°
θ
right
270°

Fig. 17

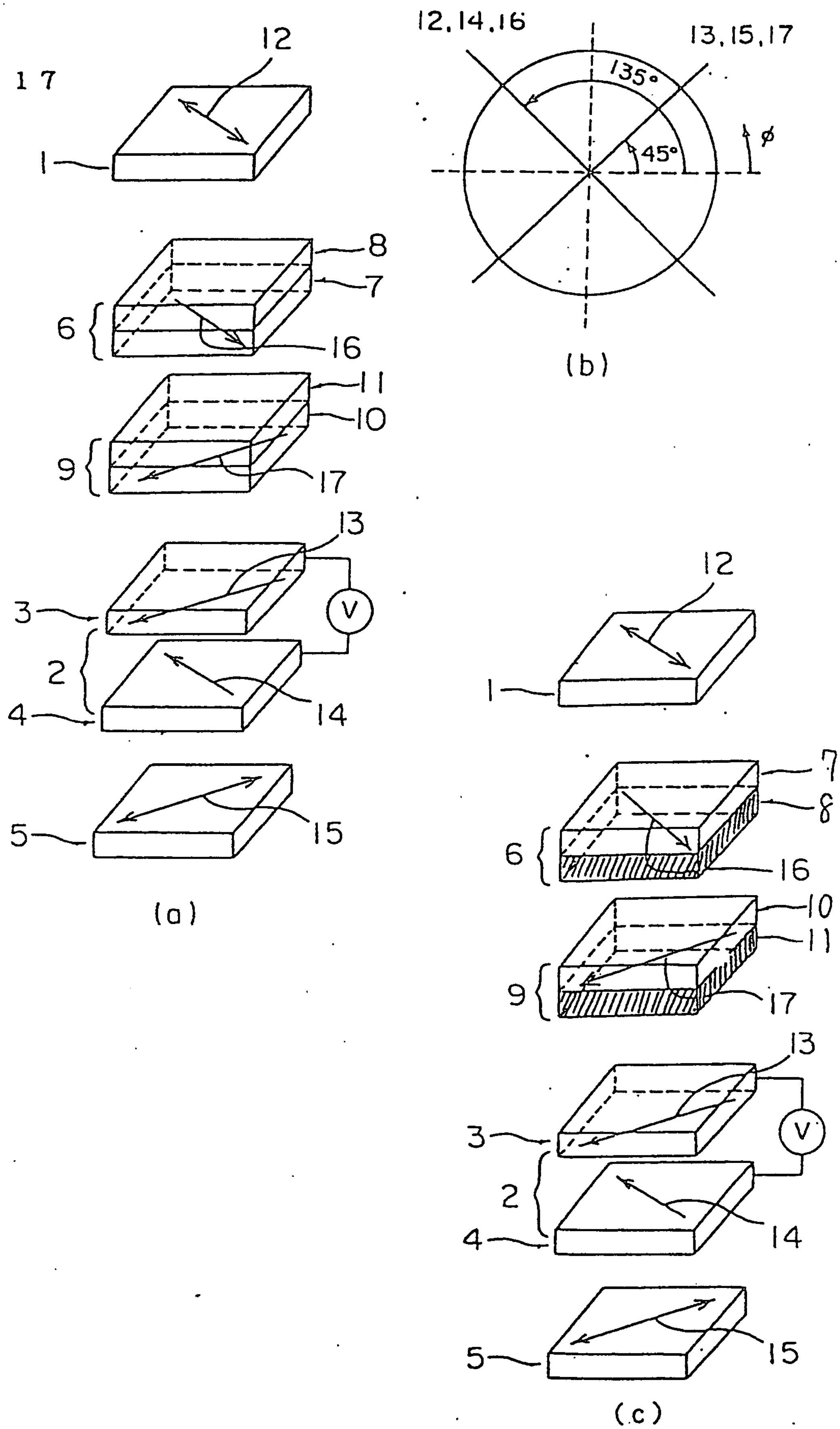


Fig. 18

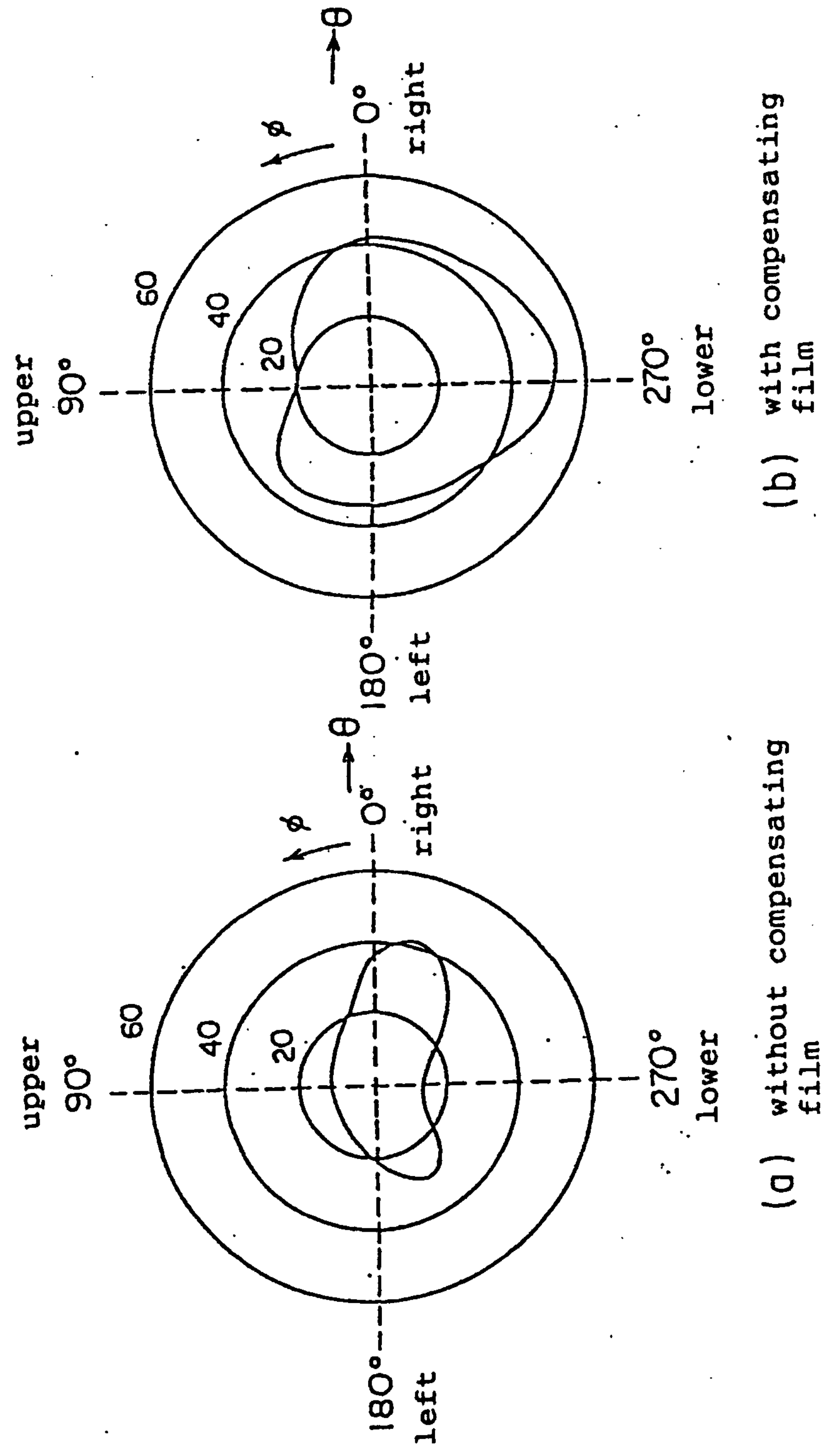
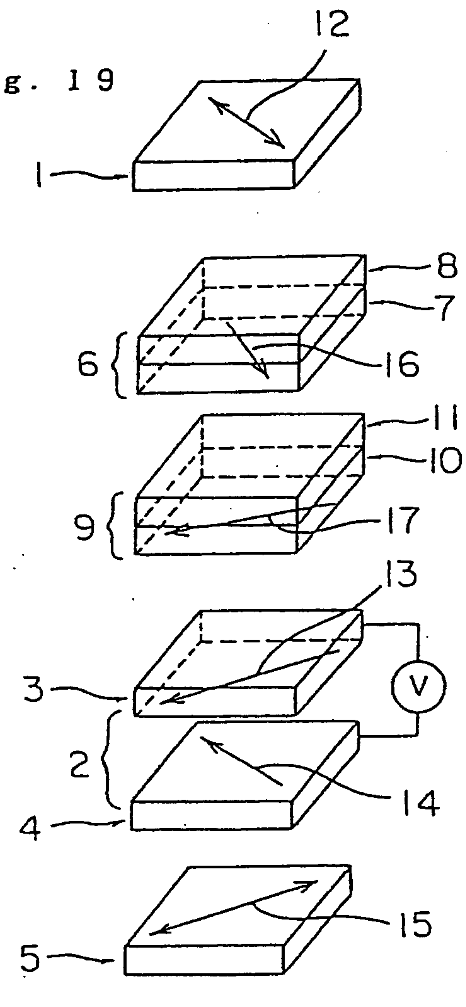
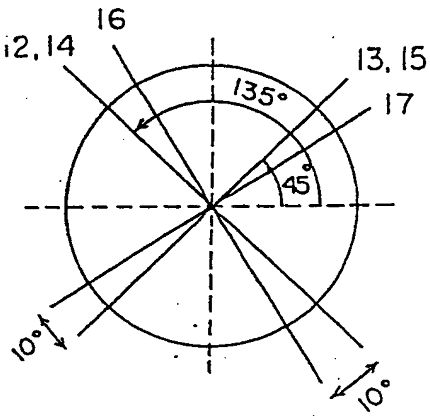

upper
90°
60
40
20
270°
lower
0°
right
180°
left
φ
θ
(a) without compensating film
(b) with compensating film

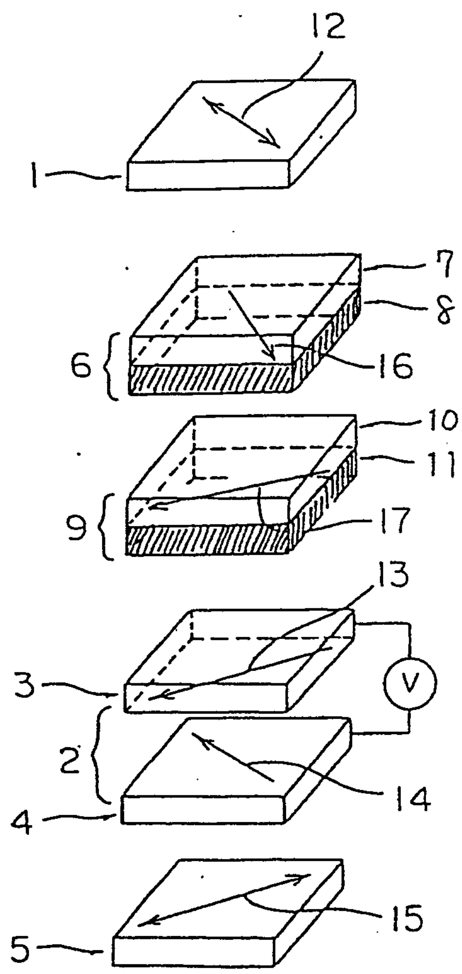
Fig. 19



(a)



(b)



(c)

Fig. 20

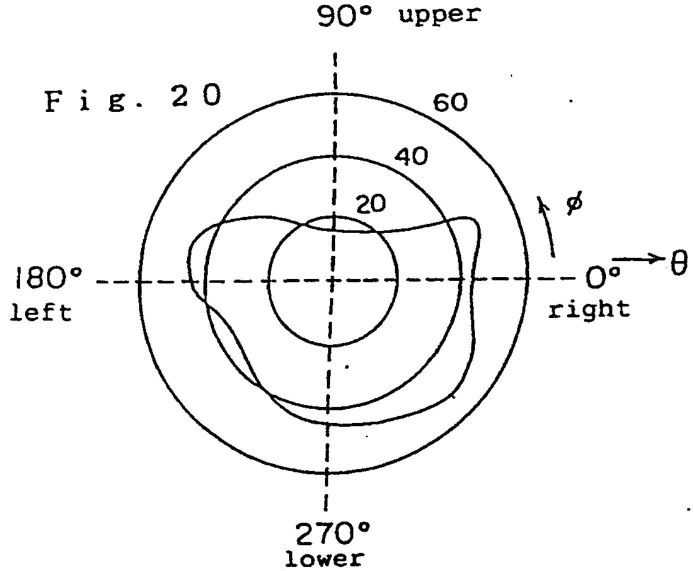


Fig. 21

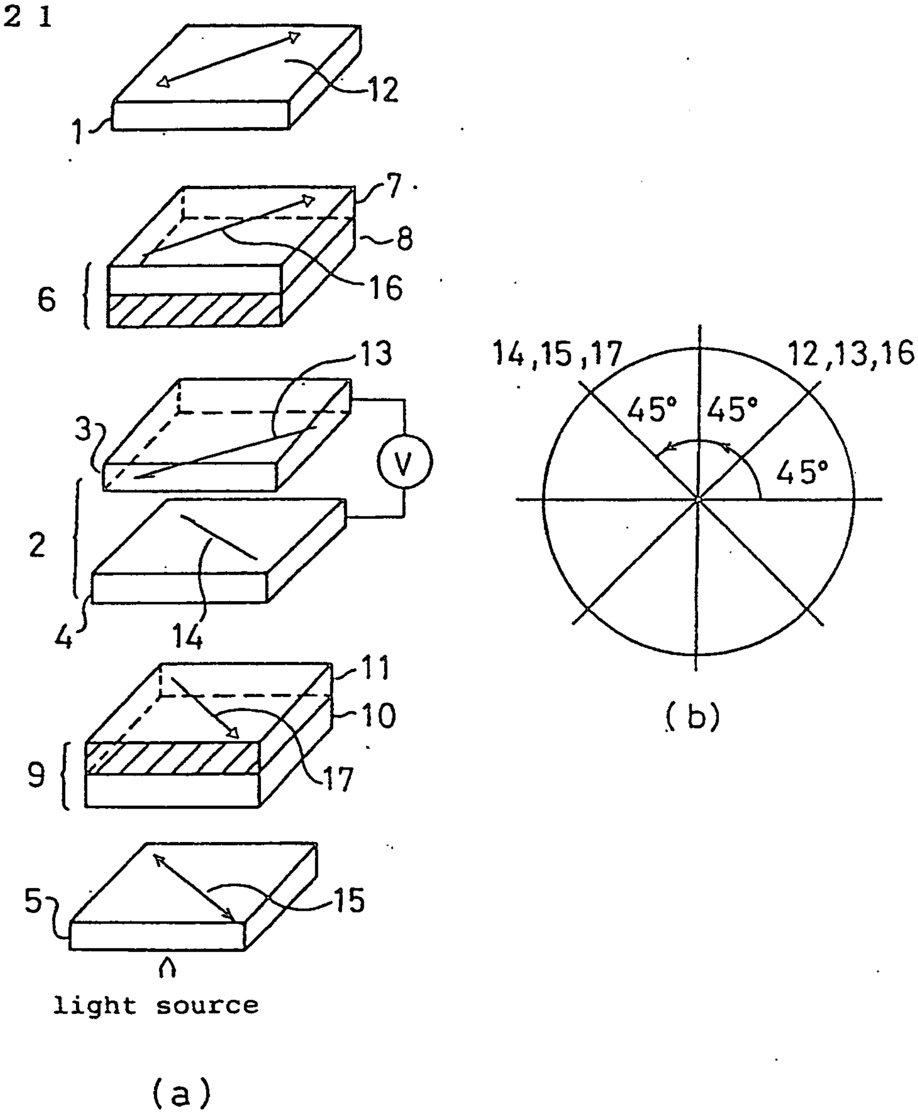

12
1
7
8
16
6
13
3
V
2
4
14
11
10
17
9
5
15
light source
(a)
14,15,17
12,13,16
45°
45°
45°
(b)

Fig. 22

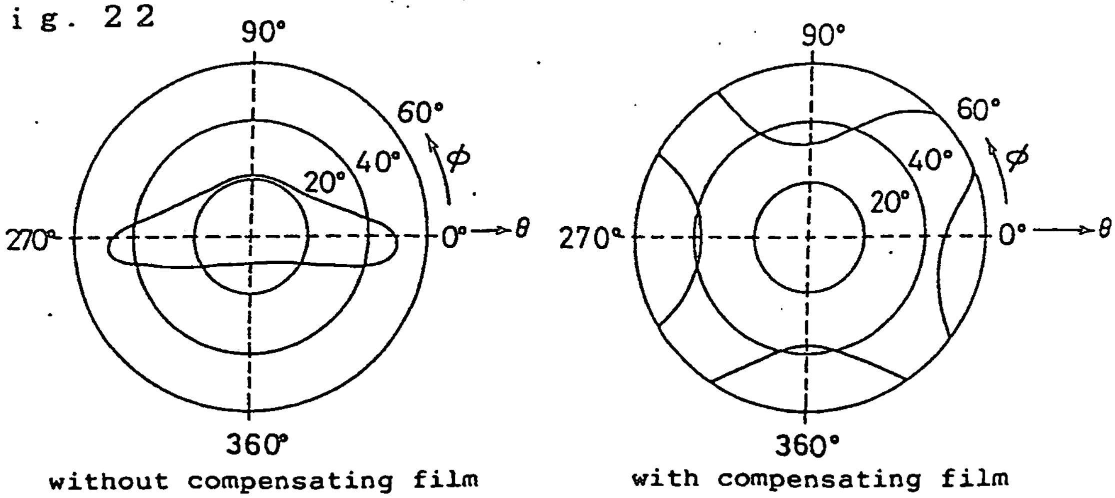
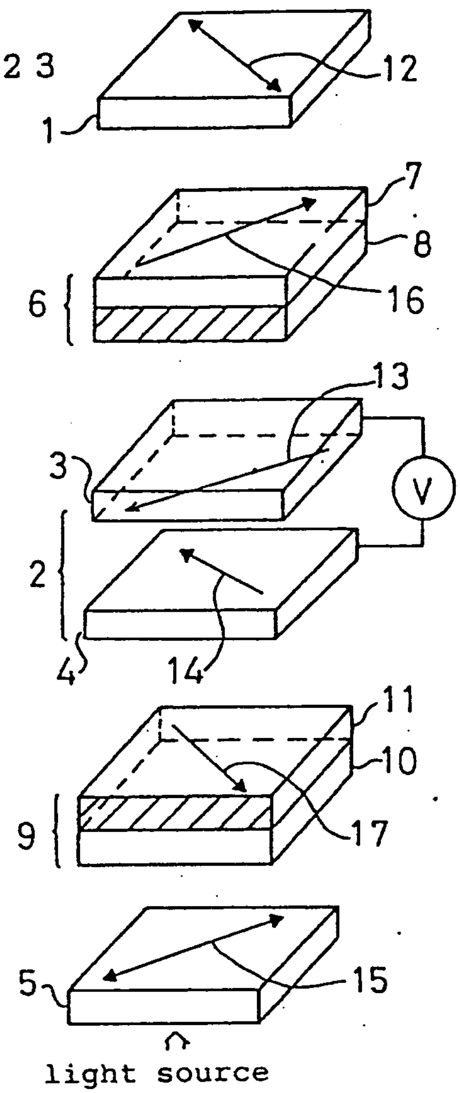
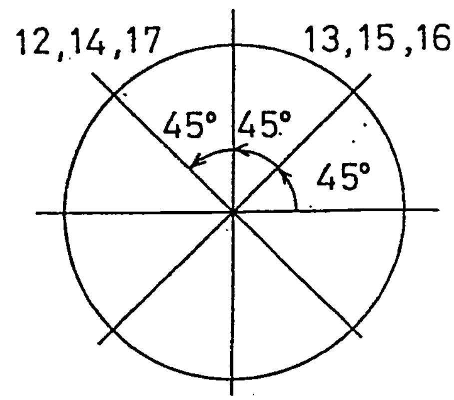

90°
60°
40°
20°
φ
270°
0°
θ
360°
without compensating film
90°
60°
40°
20°
φ
270°
0°
θ
360°
with compensating film

Fig. 23



(a)



(b)

Fig. 24

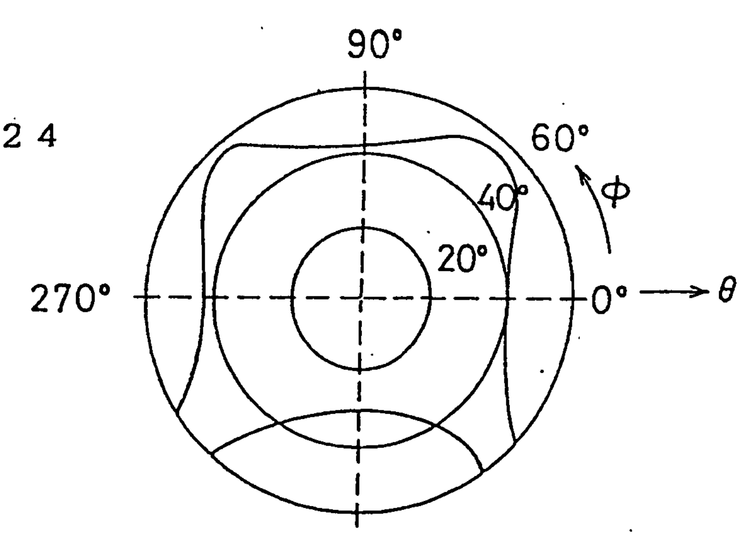


Fig. 25

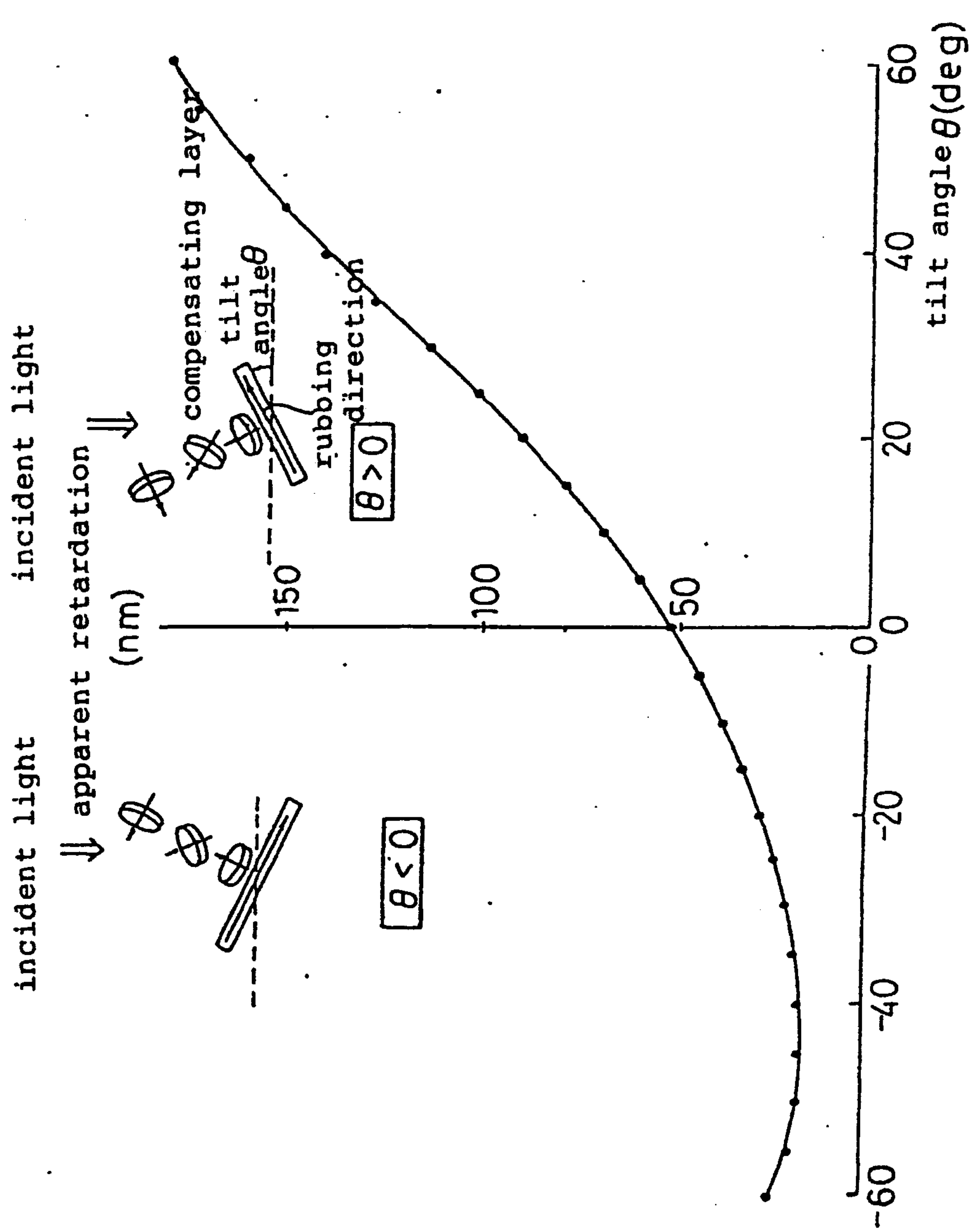
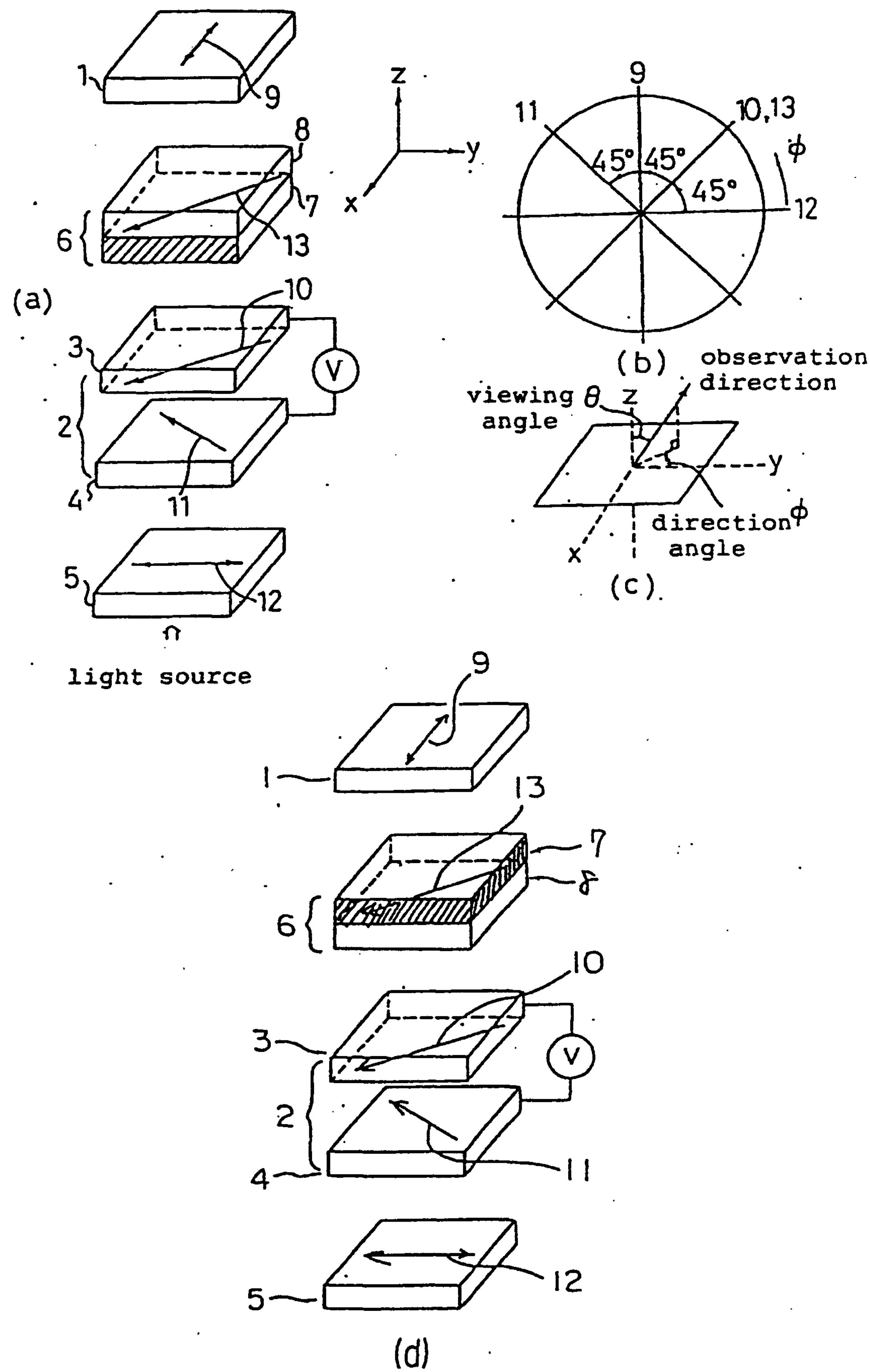
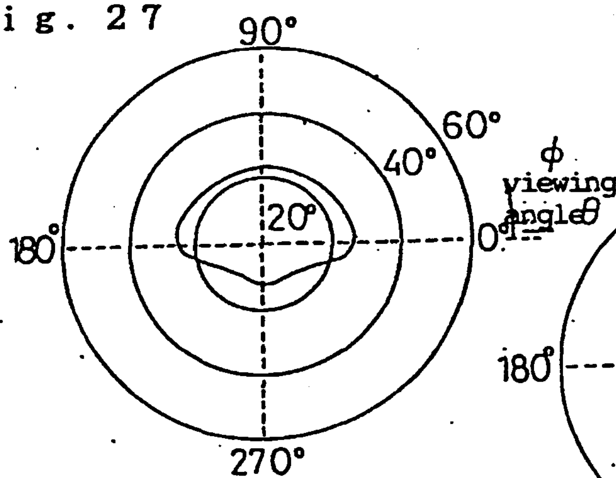

incident light
incident light
apparent retardation
(nm)
compensating layer
tilt
angle θ
rubbing
direction
θ > 0
θ < 0
150
100
50
0
-60
-40
-20
0
20
40
60
tilt angle θ(deg)

Fig. 26

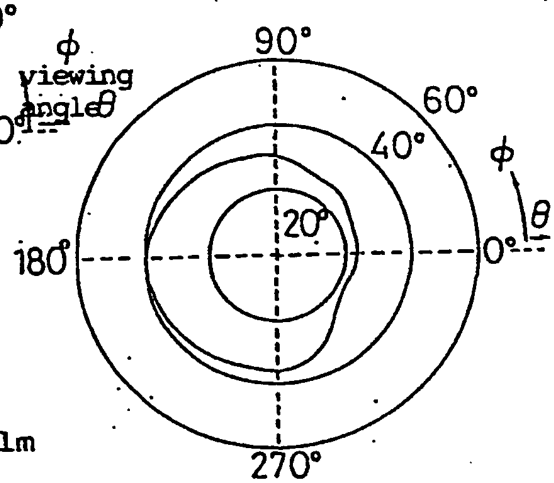


1
9
8
7
13
6
(a)
10
3
V
2
11
4
5
12
light source
z
y
x
9
11
10,13
45°
45°
45°
φ
12
(b)
observation direction
viewing angle
θ
z
y
direction angle
φ
x
(c)
9
1
13
7
8
6
10
3
V
2
4
11
12
5
(d)

Fig. 27



(a) without compensating film



(b) with compensating film

Fig. 28

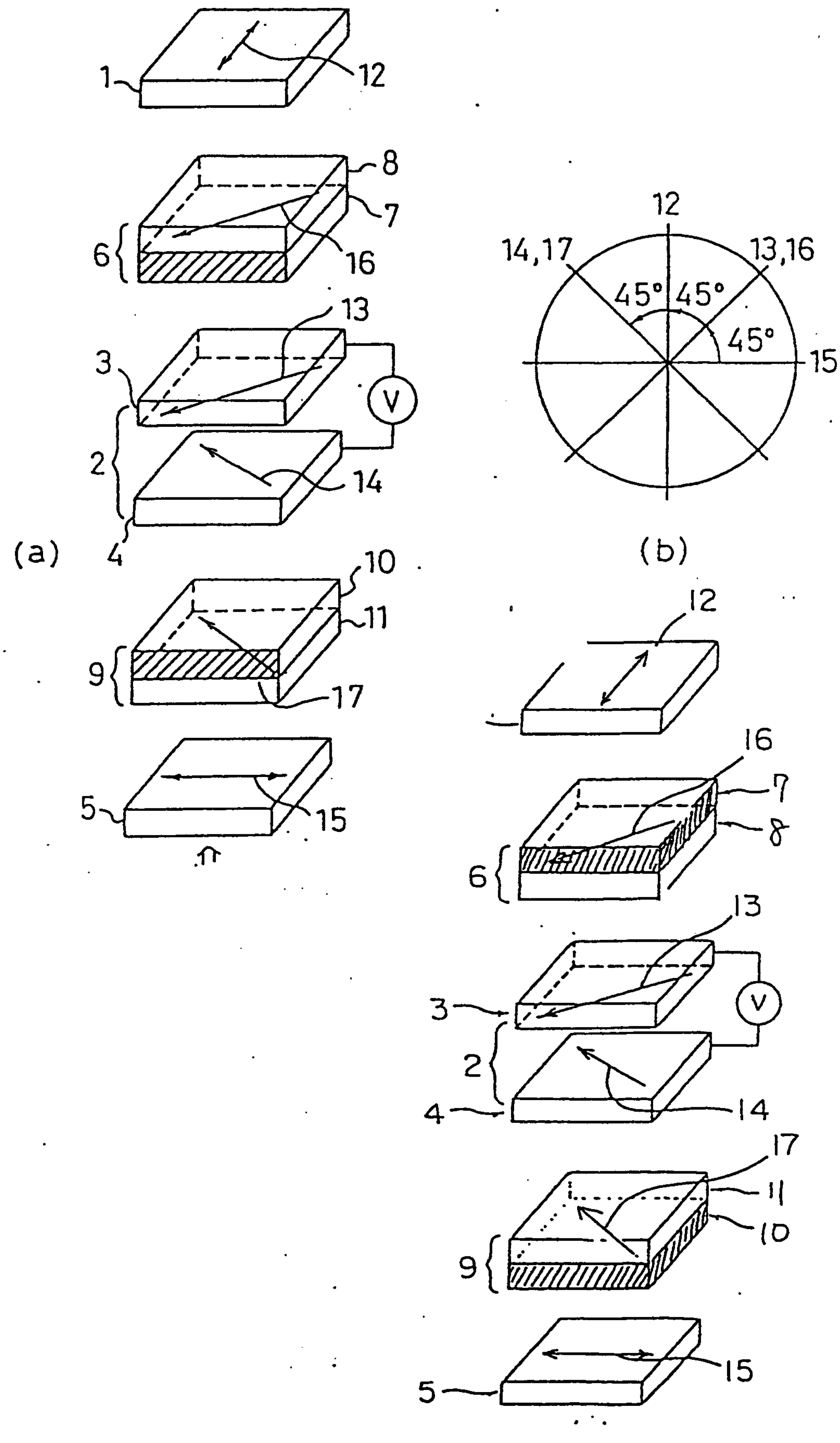

1
12
8
7
6
16
13
3
V
2
14
4
(a)
10
11
9
17
5
15
12
14,17
13,16
45°
45°
45°
15
(b)
12
16
7
8
6
13
3
V
2
4
14
17
11
10
9
5
15

Fig. 29

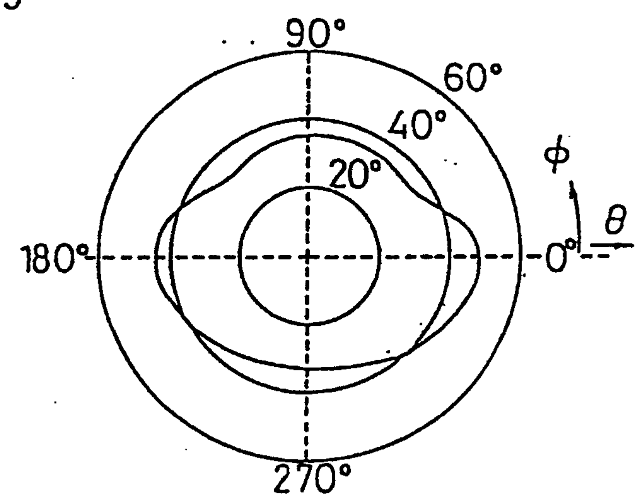


Fig. 30

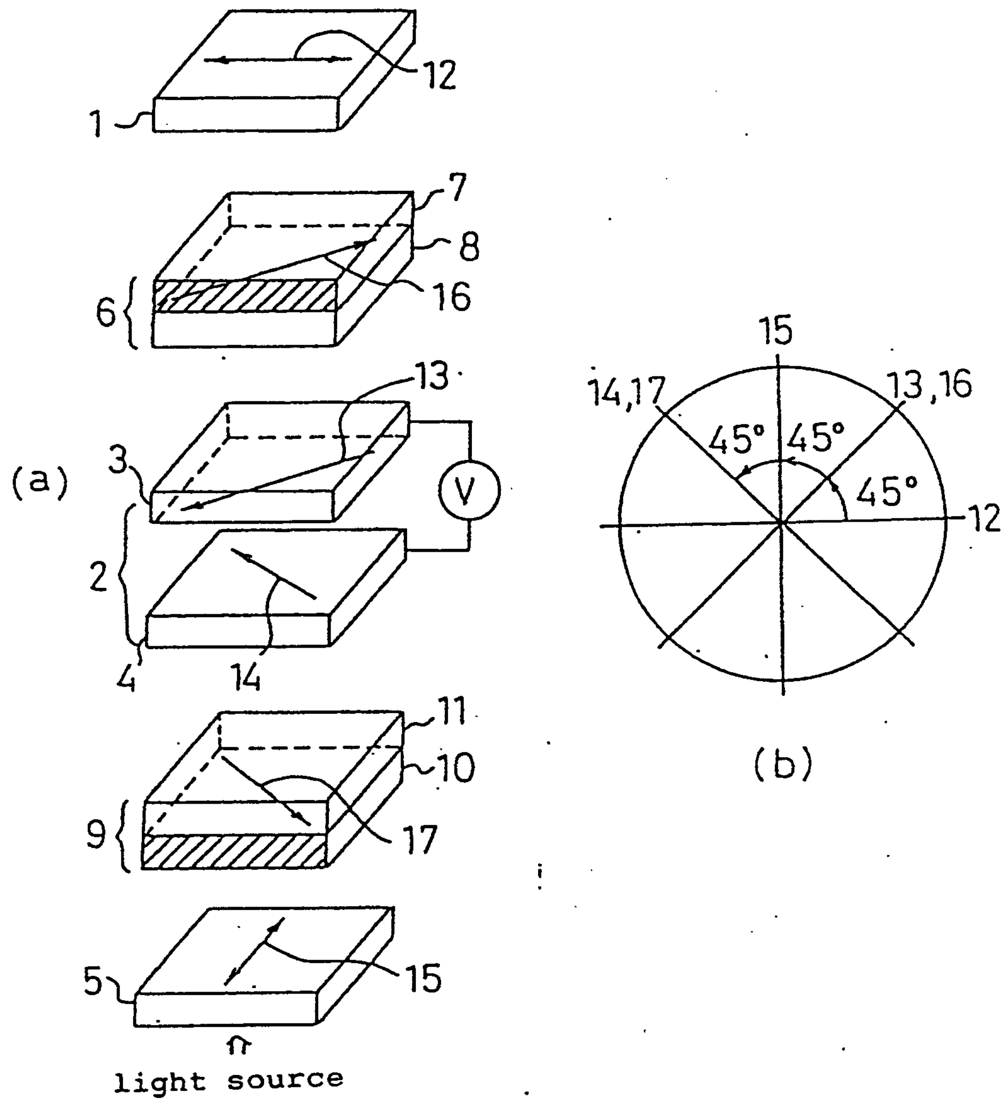
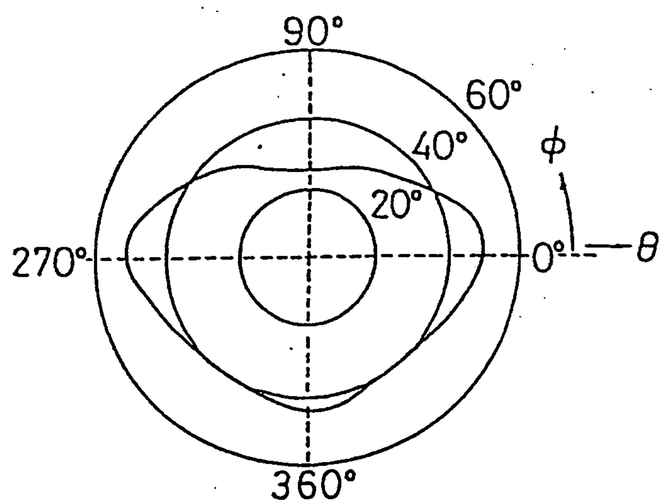


Fig. 31



230

Fig. 32

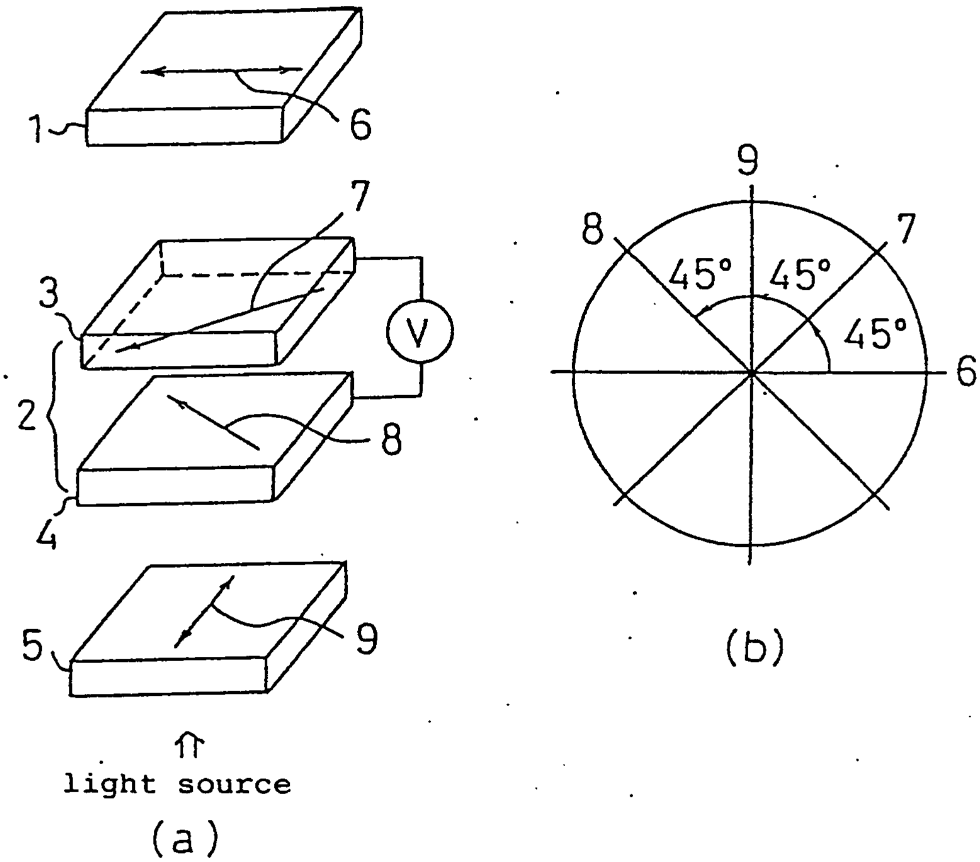

1
6
7
3
V
2
8
4
5
9
light source
(a)
9
8
7
45°
45°
45°
6
(b)

Fig. 33

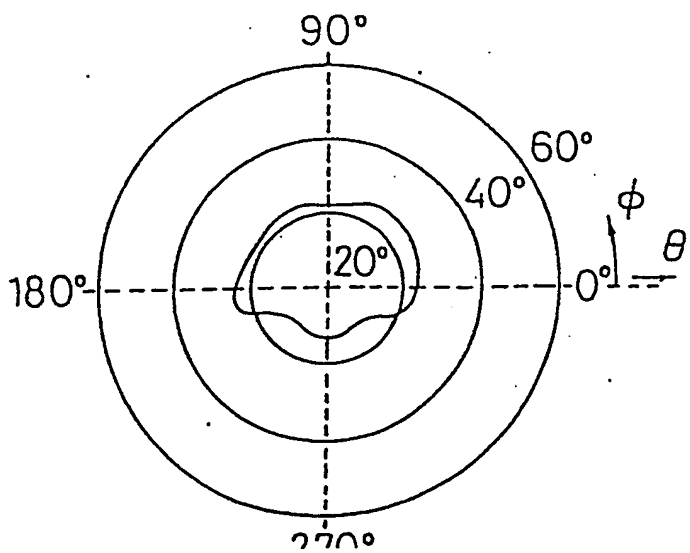
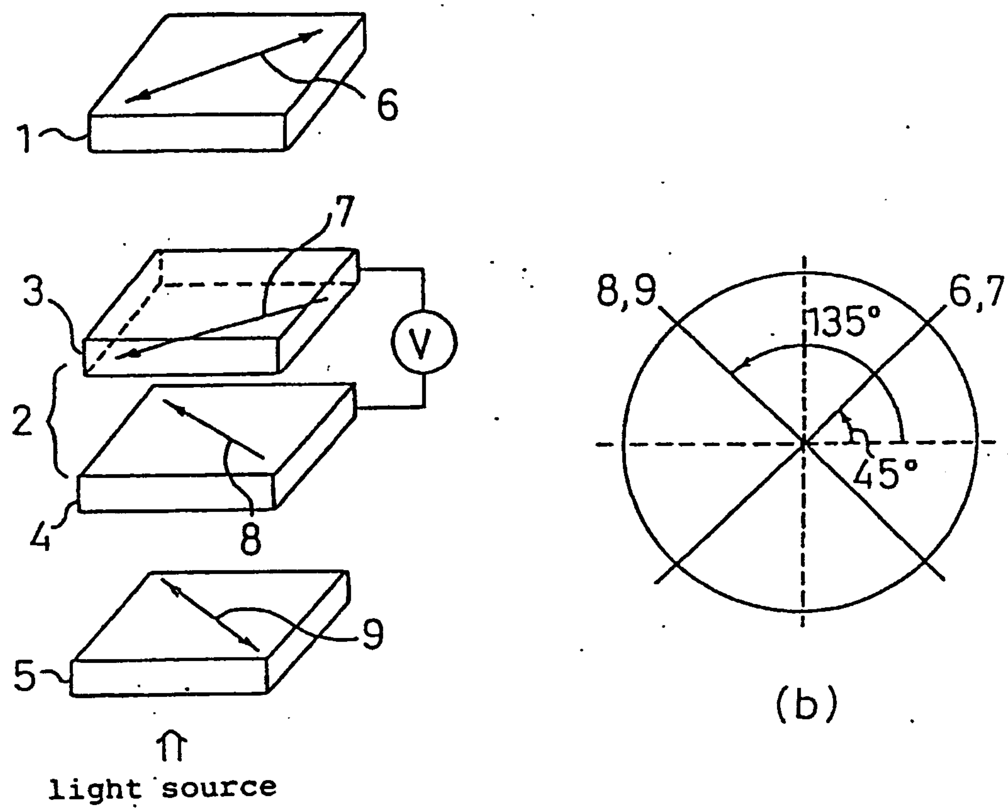

90°
60°
40°
ϕ
θ
20°
180°
0°

Fig. 34



(a)

(b)

Fig. 35

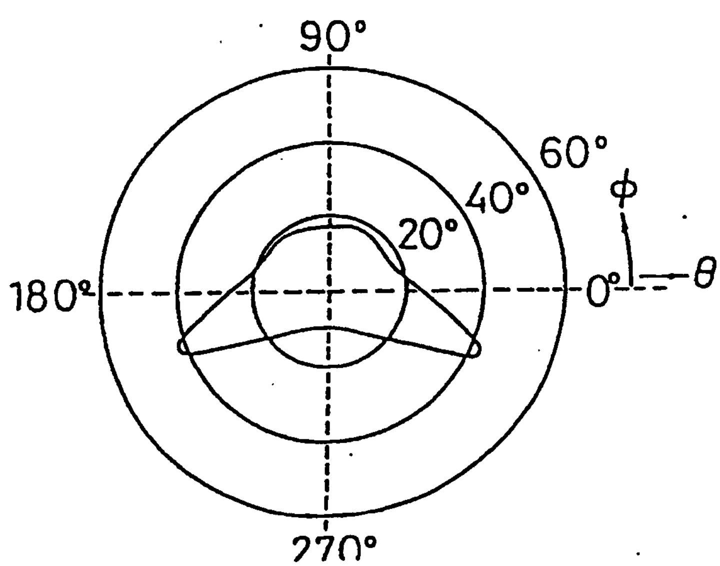
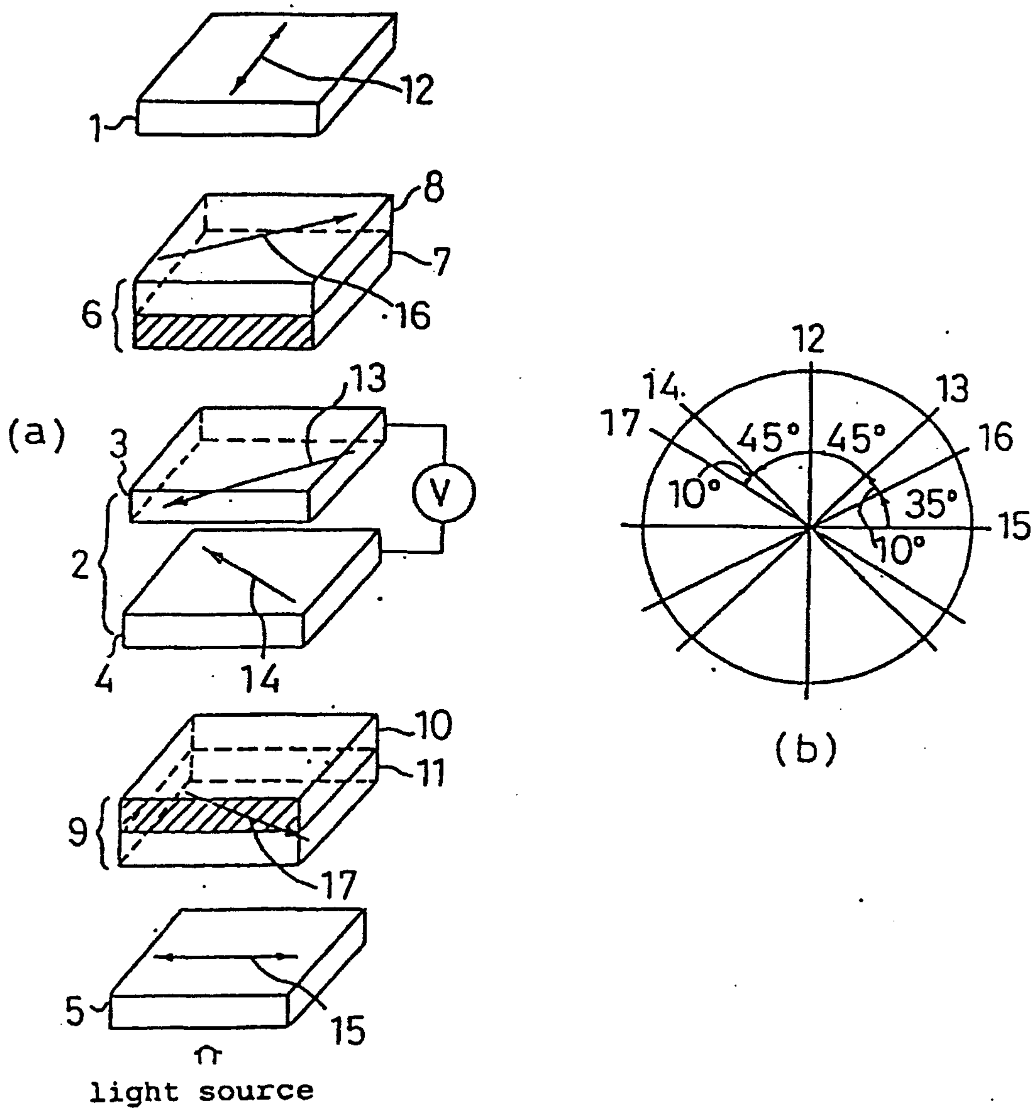
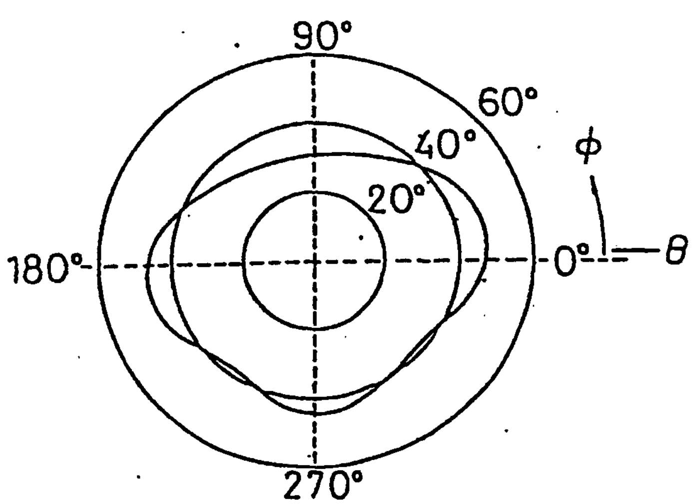


Fig. 36



12
1
8
7
6
16
13
(a)
3
V
2
4
14
10
11
9
17
5
15
light source
12
14
13
17
45°
45°
16
10°
35°
15
10°
(b)

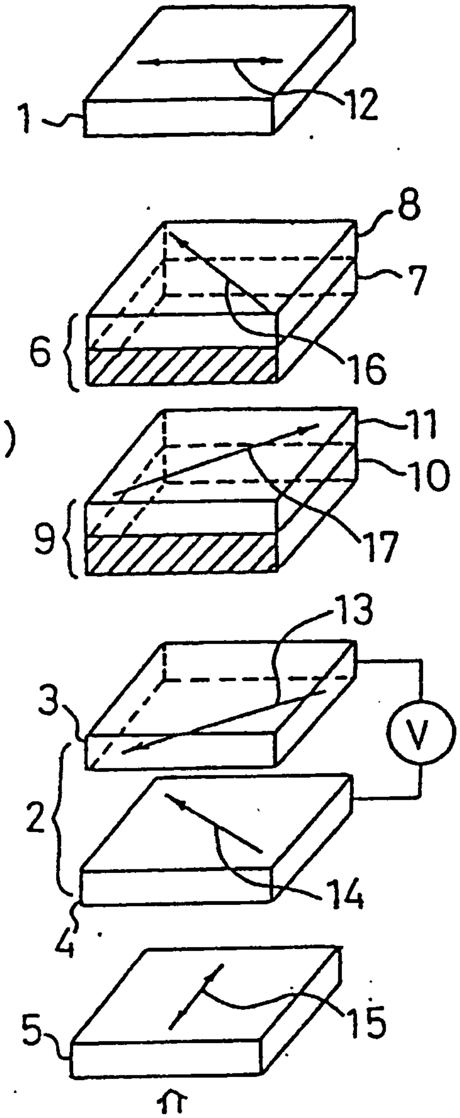
Fig. 37

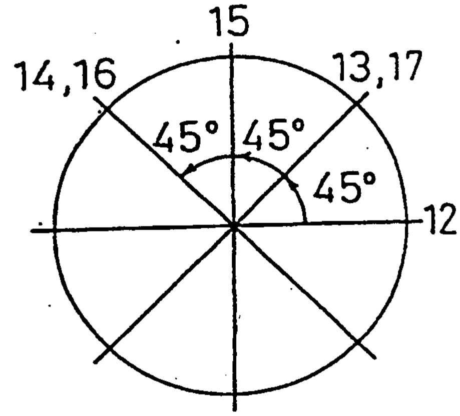


90°
60°
40°
20°
180°
0°
270°
φ
θ

Fig. 38

(a)





(b)

Fig. 39

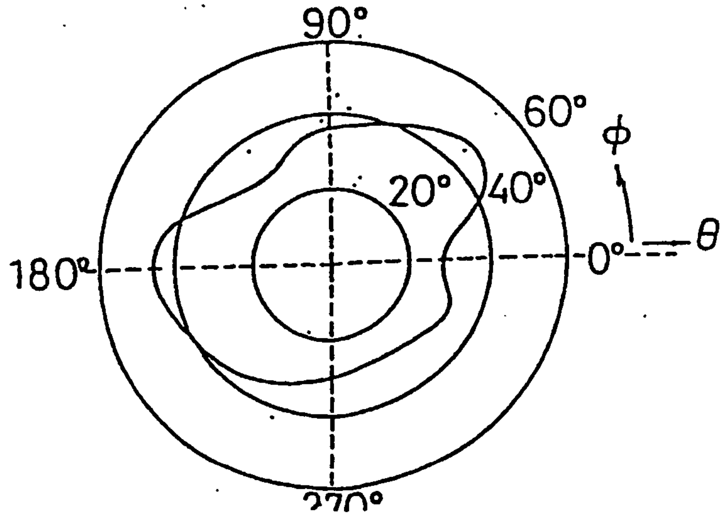
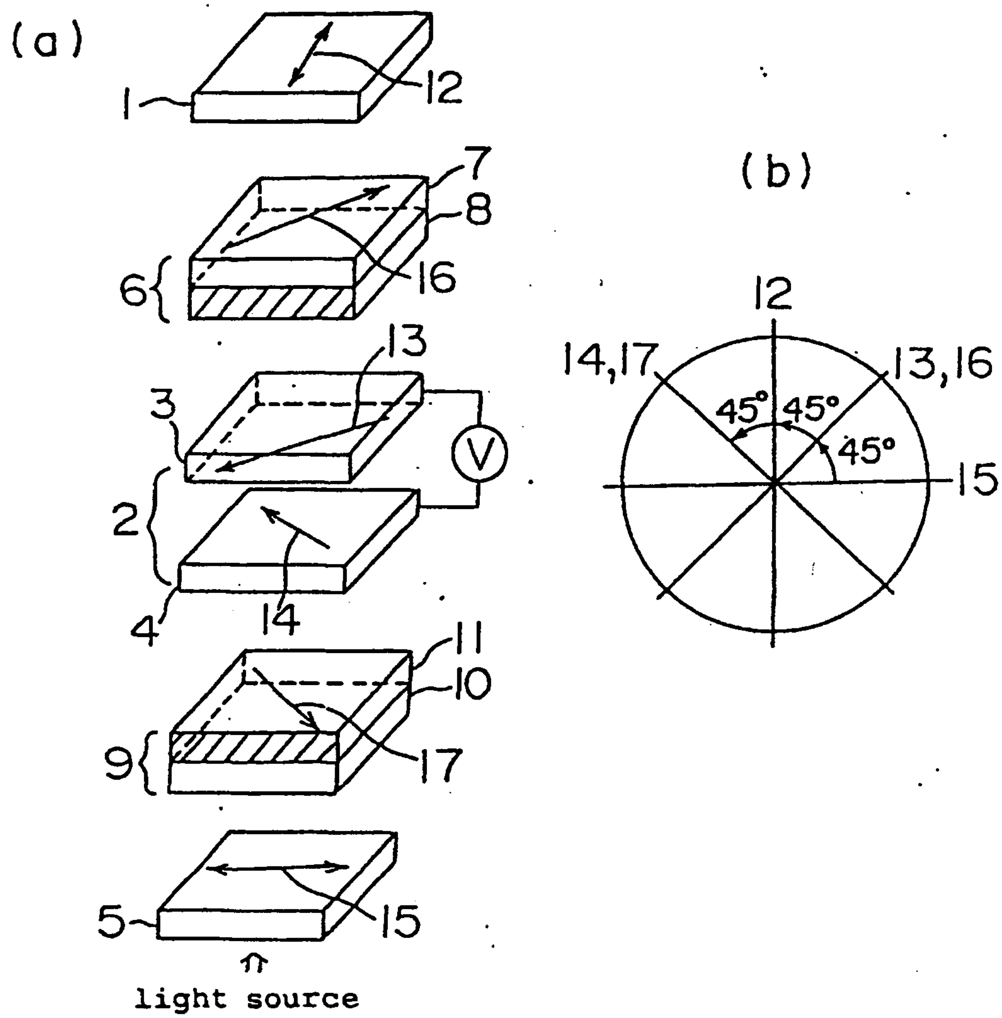


Fig. 40


(a)
1
12
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8
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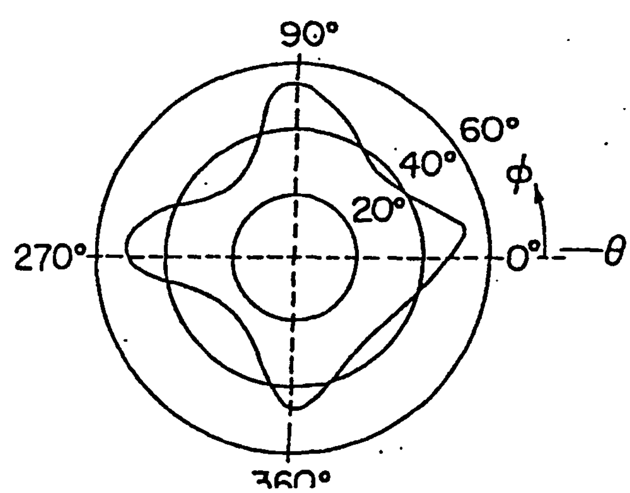
16
13
3
V
2
4
14
11
10
9
17
5
15
light source
(b)
12
14,17
13,16
45°
45°
45°
15

Fig. 41


90°
60°
40°
ϕ
20°
270°
0°
θ
360°

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP96/00947

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 G02B5/30, G02F1/1335

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^6 G02B5/30, G02F1/1335

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926 - 1996
Kokai Jitsuyo Shinan Koho	1971 - 1996

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 56-90878, A (Thomson-CSF), July 23, 1981 (23. 07. 81) & EP, 30879, A1 & US, 4333709, A & FR, 2470788, B1 & FR, 2476861, B1 & EP, 30879, B1	1 - 25
A	DE, 3911620, A1 (Merck Patent GmbH), April 8, 1989 (08. 04. 89)	1 - 25
A	JP, 04-500284, A (Merck Patent GmbH), January 16, 1992 (16. 01. 92) & WO, 90/16005, A1 & DE, 3925382, A1 & EP, 428688, A1 & US, 5308535, A & EP, 428688, B1	1 - 25
A	JP, 06-214116, A (Fuji Photo Film Co., Ltd.), August 5, 1994 (05. 08. 94) & DE, 4339395, A1 & GB, 2272779, A1	1 - 25
P	JP, 07-134213, A (Fuji Photo Film Co., Ltd.), May 23, 1995 (23. 05. 95)(Family: none)	1 - 25

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Date of the actual completion of the international search	Date of mailing of the international search report
May 9, 1996 (09. 05. 96)	May 21, 1996 (21. 05. 96)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP96/00947

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P	JP, 07-146409, A (Fuji Photo Film Co., Ltd.), June 6, 1995 (06. 06. 95) & EP, 656559, A1	1 - 25

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